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Wall thickness of full weight pipe 14" and above = .375"
Wall thickness of extra strong pipe 14" and above = .50"

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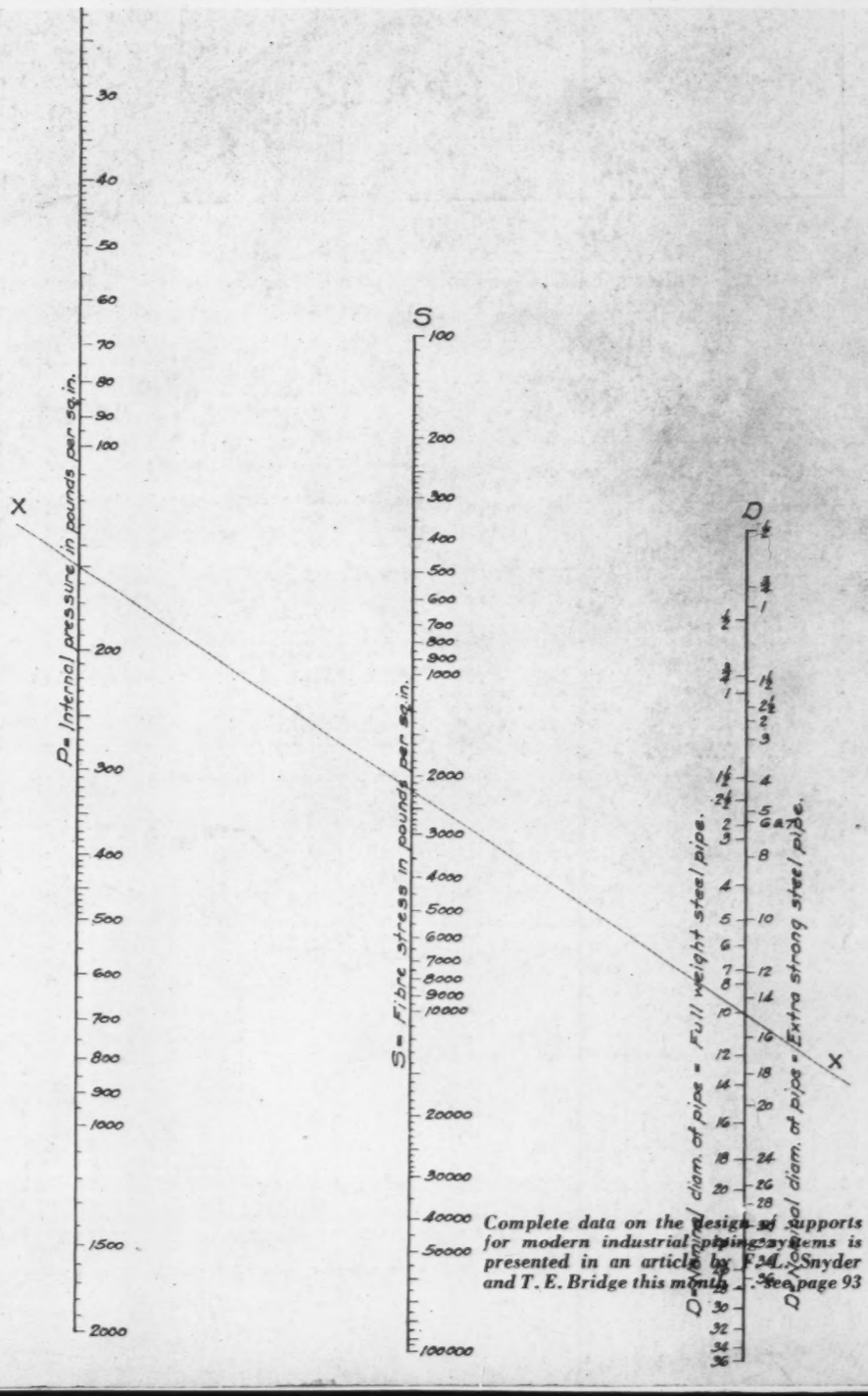
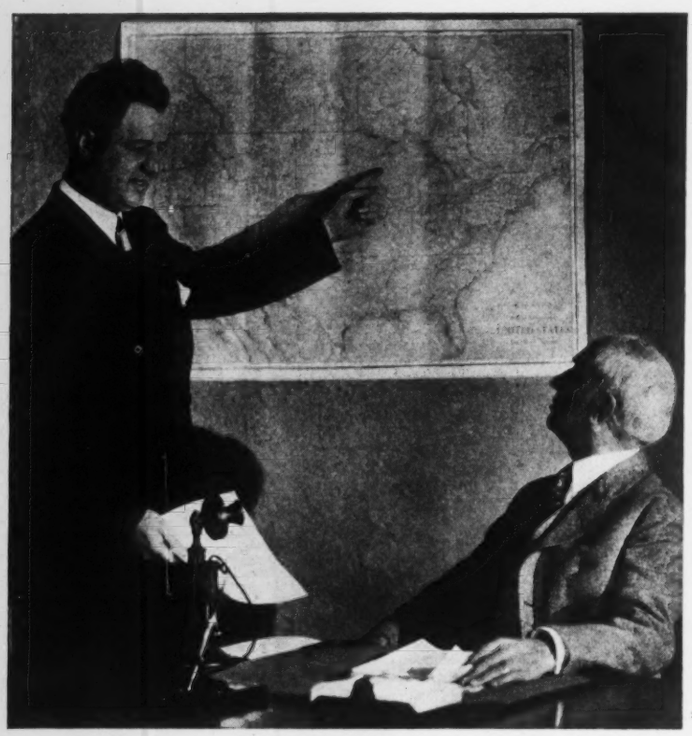
Heating · Piping and Air Conditioning


P = Internal pressure in pounds per sq. in.
S = Fibre stress in pounds per sq. in.
D = Nominal diam. of pipe = Full weight steel pipe.
D = Nominal diam. of pipe = Extra strong steel pipe.
X
X

Complete data on the design of supports for modern industrial piping systems is presented in an article by F. J. L. Snyder and T. E. Bridge this month. See page 93



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THE EDITOR'S PAGE

•A spirit of enthusiasm and optimism featured the "Big Week" of the industry in Chicago last month; attendance at the Fourth International Heating and Ventilating Exposition—The Air Conditioning Show—met all expectations. Visitors came from coast to coast, from Canada, Switzerland, Australia, South America, and other parts of the globe. Exhibits were elaborate, touched upon almost every phase of air conditioning, ventilating, and heating. Many pieces of equipment were in operation, and numerous operating models and test set-ups attracted a keenly interested crowd. Numerous recent developments were introduced. . . . Exhibitors reported sales way up, thought it the best show ever, predicted one twice its size for 1938. . . . Over 1200 registered for the annual meeting of the *American Society of Heating and Ventilating Engineers* held the same week, and the morning technical sessions were unusually well attended, the meeting hall being filled to capacity most of the time. Two of the papers which were presented and the report of the Society's committee on research appear in this issue.

•An unexpected guest at the annual *A. S. H. V. E.* banquet on Wednesday evening of the "Big Week" was the daughter of Dean Anderson, herself an engineer, who saw John Howatt, retiring president of the *A. S. H. V. E.*, present the F. Paul Anderson medal to Dr. Arthur Cutts Willard, president of the University of Illinois. Following the presentation, Dr. Willard was awarded a memento symbolizing the friendship and appreciation of the *National Warm Air Heating and Air Conditioning Association* by H. T. Richardson, its president.

•Some 200 visitors to Chicago for the Exposition and Society meetings toured the Corwith plant of Crane Co. Friday of the "Big Week," were welcomed at a luncheon served at the plant by C. B. Nolte, who introduced Mr. Howatt, and Prof. G. L. Larson, the *A. S. H. V. E.'s* 1936 president. . . . The visitors were conducted on an inspection of the manufacturing departments and the laboratory for thermal research.

•A year of rapidly increasing business and sales volume for the ventilation and air conditioning industry during 1936 was forecast by the members of the *National Association of Fan Manufacturers* during their annual meeting last month. . . . The following officers were elected: President, John M. Frank, Ilg Electric Ventilating Co.; Vice-President, Fred Herlan, B. F. Sturtevant Co.; Secretary, L. O. Monroe.

•A two-day conference on air conditioning is to be held at the University of Illinois, Urbana, in May, according to M. K. Fahnestock of the U. of I., who was in Chicago for the *A. S. H. V. E.* meeting and the Exposition. Purpose is to give a non-technical summary of air conditioning, its problems, methods, and advantages to property owners and operators. . . . Prof. R. A. Norman of Iowa State, who dropped in at HEATING, PIPING AND AIR CONDITIONING's booth at the Exposition, said a conference on air conditioning and an exhibit of equipment is being planned for Ames in March. . . . Anker Winther, author of the article on the modernization of the American building by air conditioning published last month and a visitor to our exhibit, reported considerable interest in the method of duct fabrication described in his paper. . . . The air conditioning division of the electrical association in Cincinnati is sponsoring a well attended series of lectures on air conditioning for architects, engineers, building owners and managers, and others, according to Mr. Winther.

•The sub-zero weather, a more or less unpopular feature of Chicago to Exposition visitors, at least stimulated interest in efficient heating and insulation. . . . One pipe covering manufacturer exhibiting at the show reported requests for information and probable sales to a number of apartment building owners and managers, one of whom said it took 18 lb steam pressure to heat the fourth floor of his building before the piping was properly insulated, 2 lb after the work was done.

•Alfred P. Sloan, Jr., announced last month that General Motors plans a program of expansion in the air conditioning industry, has organized a new corporation for developing and marketing air conditioning and heating equipment known as Delco-Frigidaire Conditioning Corp. . . . "General Motors is encouraged by the thought that air conditioning, in its complete phase, namely, the conditioning of air the year-'round, is needed in virtually every type and size of business, industrial or residential building," said Mr. Sloan.

•The tea industry of Ceylon and elsewhere affords a potential field for air conditioning, according to Consul R. L. Buell in a report made public by the Department of Commerce. It has been ascertained, the report states, that tea grown at an altitude of 4,000 ft and processed at an altitude of 6,000 ft has a much finer flavor than if manufactured at the altitude where grown. It is therefore apparent, Consul Buell points out, that the major influences are those of temperature and humidity. Furthermore, tea that has been withered, rolled, fermented and fired on a damp, rainy day has a very different quality from that manufactured on a dry, sunny day. . . . Air conditioning should enable tea growers to improve the quality of tea made of leaves grown at a lower altitude, and also to attain a uniformity in the finished product that is not now possible because of variable climatic conditions, the consul believes.

•The division of simplified practice of the National Bureau of Standards has announced that Simplified Practice Recommendations R57-32, Wrought Iron and Wrought Steel Pipe, Valves, and Fittings, has been reaffirmed without change by the standing committee of the industry. This simplification program, which is concerned with the nominal inside diameter, outside diameter, and approximate thickness for standard weight, extra strong, and double extra strong wrought iron and wrought steel pipe, was originally effective September 1, 1926, and was revised in 1932. . . . Copies of the recommendation may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.

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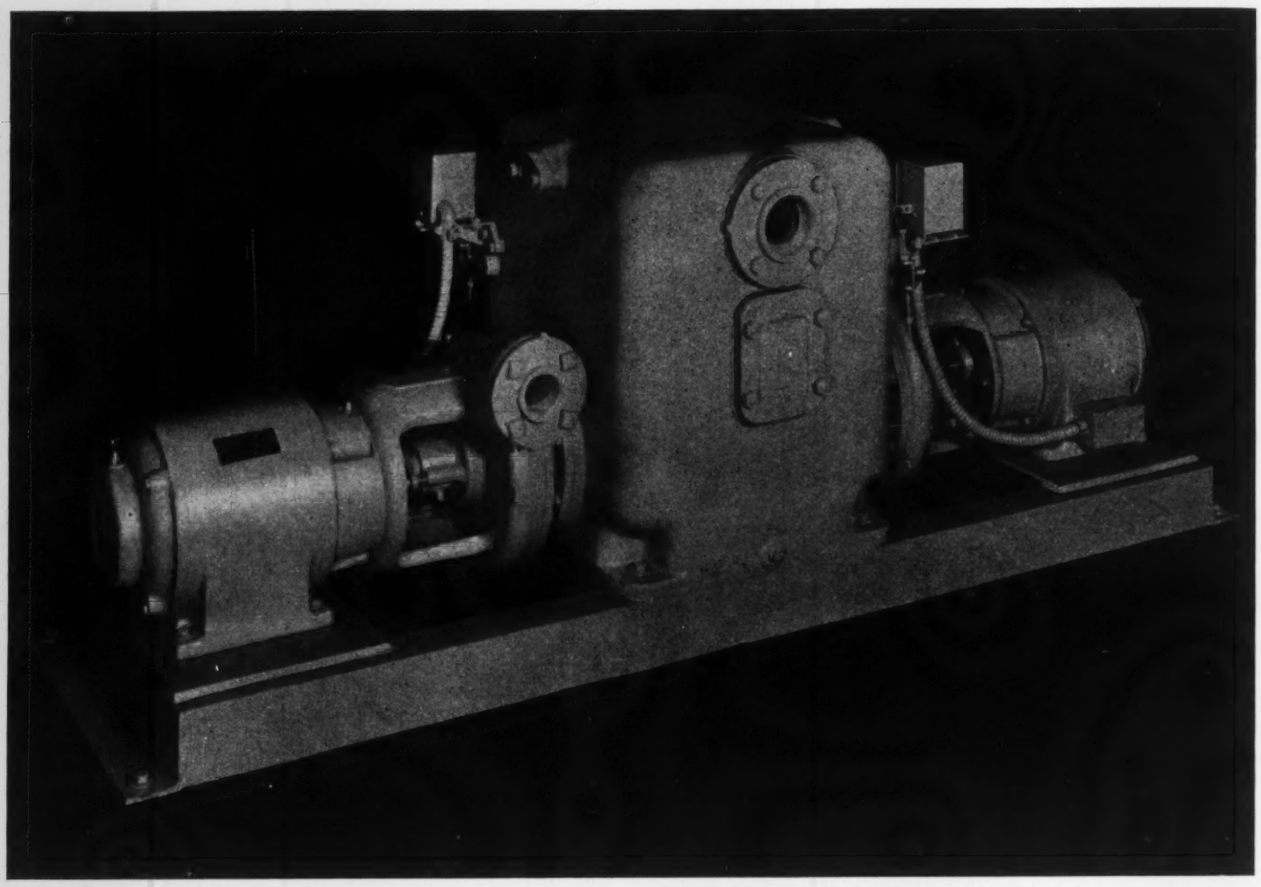
MAXIMUM EFFICIENCY FOR STEAM HEATING SYSTEMS ON HEATING, DRYING AND PROCESS WORK.



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Vol. 8, No. 2 • *February, 1936*

New Uses for the Psychrometric Chart in Simplifying Air Conditioning Problems

By **William Goodman***

THE usefulness of the psychrometric chart can be extended to solve a whole class of air conditioning problems for which it is not utilized at present. The solution of these problems on the chart not only gives an answer quickly and with the least effort, but has the additional merit of providing a picture of the action which takes place under various conditions.

In the design of an air conditioning system the amount of air to be supplied and its dry and wet bulb temperatures must be determined in order that the air supply shall have sufficient capacity to care for the estimated sensible and latent heat loads of the conditioned spaces. Obviously, if the dry bulb temperature of the air supply is too high the dry bulb temperature in the conditioned room will rise. Likewise, if the dewpoint temperature of the air supply is too high the relative humidity in the conditioned room will also rise. It is the purpose here to present a simple method of utilizing the psychrometric chart for determining both the quantity and the condition of an air supply in order to maintain a given dry bulb temperature and relative humidity in a conditioned room. This article deals only with warm weather air conditioning, when rooms must be cooled and dehumidified.

The psychrometric chart can be used to simplify the solution of many air conditioning problems for which it is not now utilized; a further advantage of the method described in this series of articles (of which this is Part 1) is that a picture of what takes place is provided .....The author explains in readable and clear manner the solving of problems by the "psych" chart, going deeply enough into the subject to make his article a treatise on air conditioning fundamentals.....The procedure advocated has been tested by one organization of air conditioning engineers, enthusiastically adopted, and is now used in its every-day work.

In the material which follows, such terms as the "moisture absorbed by the air" and the "moisture content of the air" will be used, although the use of these phrases implies that air acts like a sponge in absorbing moisture. Actually, nothing of the sort happens. Air has no affinity for moisture. We are dealing only with the tendency of every liquid to saturate the space above it with its own vapor, regardless of whether air or any other gas is present. However, this habit of speaking of the "moisture content of air" and of "moisture absorbed by the air" is so firmly established that to use a strictly correct phrasing would make a paper such as this not only difficult to read but equally difficult to write.

Absorption of Sensible Heat Gains

In any cooling system, the air supplied to a conditioned room must absorb the sensible heat gain of the room as it rises to the dry bulb temperature being maintained in the conditioned space; this is the exact converse of the action of warm air in heating a room. In the latter case the air must release sufficient heat, as it cools from the initial dry bulb temperature to the dry bulb temperature of the room, to offset the heat losses of the room.

The action of a chilled air supply in absorbing the sensible heat gain of a room is represented by the following simple equation:

$$H_s = 0.24W\ (t_r - t_s) \qquad [1]$$

where

H_s = Total sensible heat gain of the conditioned room in Btu per unit of time

W = Pounds of chilled air supplied to the conditioned room, per unit of time

t_r = Dry bulb temperature to be maintained in the conditioned room

t_s = Dry bulb temperature of the chilled air supply.

When designing a heating system, this equation (with the symbols t_r and t_s interchanged) is all that is needed to determine the required quantity of warm air and its initial temperature. Once the sensible heat losses of a room have been determined, the designer may vary the temperature of the air supply and its quantity to suit himself, always staying within the limitations of available equipment and current good practice. He may

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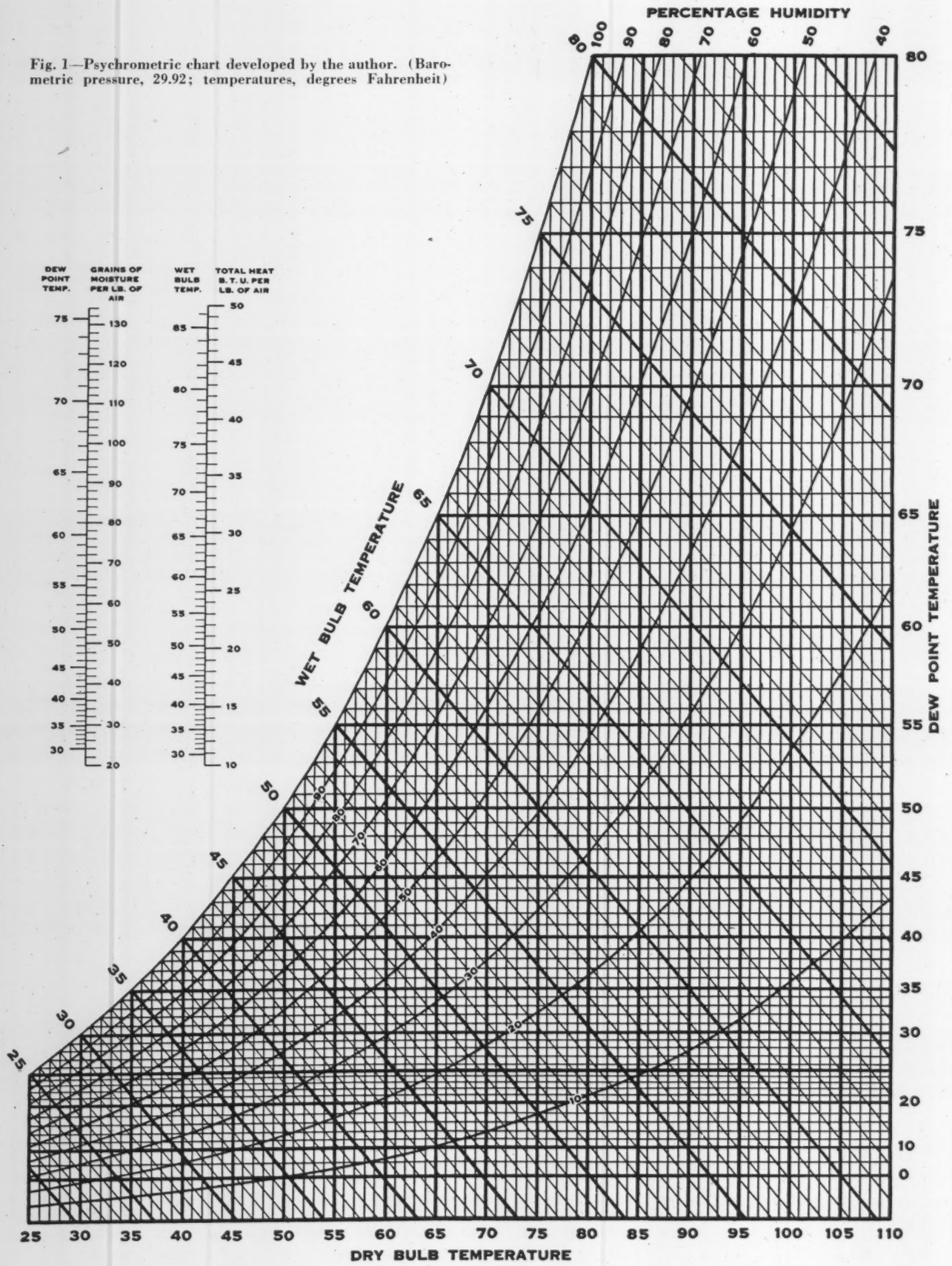
Fig. 1—Psychrometric chart developed by the author. (Barometric pressure, 29.92; temperatures, degrees Fahrenheit)



select either the temperature of the air supply or the weight of air to be circulated and solve for the remaining quantity by means of Equation 1.

Absorption of Moisture by the Air Supply

Is this true in air conditioning also? Yes, so long as only sensible heat need be considered; that is, where there is no need for dehumidification.. However, every summer air conditioning problem does involve dehumidification. This being the case, it is necessary to consider the moisture addition to the atmosphere of conditioned rooms and to provide for removing this added water vapor exactly as the sensible heat gains must be removed. One way to accomplish this is to lower the dew point of the air supply sufficiently so that upon being introduced into the conditioned room it can absorb the added water vapor. As this water vapor is absorbed, the dew point temperature of the air supply rises to the dew point temperature of the air in the conditioned room in exactly the same way as the dry bulb temperature of the air supply rises because of the sensible heat gains. Since the relative humidity of a conditioned room must be kept below a certain point, it is obvious that the dew point temperature of the room air must be held down to a point corresponding to the desired dry bulb temperature and relative humidity.

The absorption of moisture by an air supply having a lower dew point temperature than that in the conditioned room can be expressed by:

$$G = W\ (g_r - g_s) \qquad [2]$$

where

G = Total weight of water vapor released in the conditioned room per unit of time
W = Pounds of dehumidified air supplied to the conditioned room per unit of time
g_r = Moisture content of air at the dew point temperature of the air in the conditioned room, expressed in pounds of moisture per pound of air
g_s = Moisture content of air at the dew point temperature of the air supply, expressed in pounds of moisture per pound of air.

While the physical basis underlying Equation 2 is quite apparent, its use involves the weight of moisture liberated in the conditioned room. It has become almost universal practice to speak of the "latent heat gain" of a room rather than the moisture gain. The latent heat gain of a room is the heat which must be removed at the dehumidifying apparatus in order to condense the moisture absorbed by the air supply in the conditioned room. The latent heat of water vapor at low pressures is about 1150 Btu per lb. Multiplying the weight of moisture released in a conditioned room by this figure will give the latent heat gain of the room.

Absorption of Total Heat Gain

The latent heat gain of a room added to the sensible heat gain of a room gives the total heat gain. The addition of sensible heat to an air supply causes a rise in its dry bulb temperature. Likewise, the addition of moisture to an air supply causes a rise in its dew point temperature. But, the addition of both sensible and latent heat causes a rise in the wet bulb temperature of the air supply, since the total heat content of air is a function only of its wet bulb temperature. Here is an index which changes with the addition of any heat, regardless of the proportions of sensible and latent heat which make up the total. Therefore, the rise in the wet bulb temperature of the air supply due to the addition of both the sensible and latent heat gains of a conditioned room can be expressed by:

$$H_T = W\ (h_r - h_s) \qquad [3]$$

where

H_T = The total heat gain of the room in Btu per unit of time. The total heat gain is equal to the sum of the sensible and latent heat gains
W = Pounds of chilled and dehumidified air supplied to the conditioned room per unit of time
h_r = Heat content of air at the wet bulb temperature of the air in the conditioned room, expressed in Btu per lb of air
h_s = Heat content of air at the wet bulb temperature of the air supply, expressed in Btu per lb of air.

Insofar as the dry bulb temperature of the conditioned room is concerned only Equation 1 need be satisfied. But if, as is usually the case, the relative humidity must be limited, then Equation 3 must also be satisfied. Here are two equations which must be solved in order to find the amount of air which must be supplied, as well as its condition, if the required dry bulb temperature and relative humidity are to be maintained in a conditioned room which has a given sensible and latent heat gain. Proceeding, therefore, with the solution of these equations, we divide Equation 1 by Equation 3, which gives

$$\frac{H_s}{H_T} = 0.24\ \frac{W(t_r - t_s)}{W(h_r - h_s)}$$

which reduces to

$$N = 0.24\ \frac{t_r - t_s}{h_r - h_s} \qquad [4]$$

where all symbols are as heretofore, except

N = Sensible heat ratio; that is, the proportion of the total heat gain which is sensible heat, the balance being latent heat.

An immensely important conclusion can be drawn from Equation 4: **In any conditioned room in which a given dry and wet bulb temperature is to be maintained, the dry and wet bulb temperatures of the air supply are determined only by the ratio of the sensible heat gain to the total heat gain. The determination of the condition of the air supply is independent of the *actual values* of the sensible and latent heat gains.**

Suppose certain given dry and wet bulb temperatures are to be maintained in a room where the sensible and latent heat gains, and therefore the sensible ratio, are known. This being the case, the only values which it would be necessary to find by means of Equation 4 are the dry and wet bulb temperatures of the air supply. For example, assume that the dry bulb temperature of a conditioned room is to be maintained at 80 F and the wet bulb temperature at 67 F. Also, assume that of the total heat gain 85 per cent is sensible and 15 per cent latent. Substituting in Equation 4

$$0.85 = 0.24\ \frac{80 - t_s}{31.15 - h_s}$$

where 31.15 is the total heat content of air at a wet bulb temperature of 67 F.

Use of the Psychrometric Chart

In this one equation there are two values which must be found; the dry bulb temperature and the wet bulb temperature of the air supply. Obviously, any value may be assumed for one of the two unknown quantities

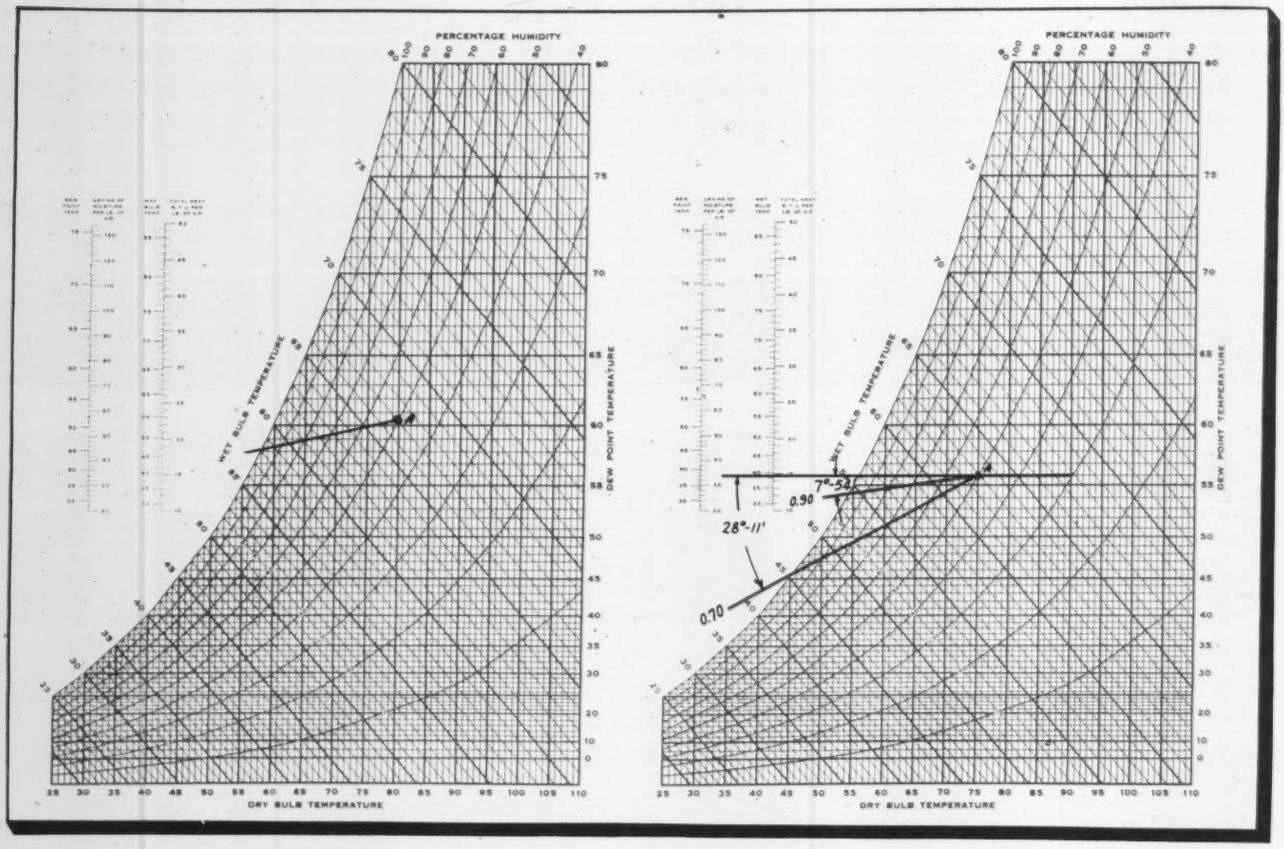


Fig. 2—Straight line plotted on psychrometric chart from Equation 4 for a room condition of 80 F dry bulb, 67 F wet bulb, and a sensible heat ratio of 0.85. Note that the line passes through point *A* representing the room condition

Fig. 3—Two heat ratio lines drawn on psychrometric chart for room condition of 75 F dry bulb and 50 per cent relative humidity, one for a sensible heat ratio of 0.90 and the other for a ratio of 0.70. The 0.70 line is steeper, since more latent heat must be absorbed by the air supply when the sensible heat gain is 70 per cent of the total gain than when it is 90 per cent

and the equation solved for the remaining one. Now, suppose that several different values are assumed for the dry bulb temperature and Equation 4 is used to find the wet bulb temperature required. This will result in several combinations of dry and wet bulb temperatures for the air supply, any one of which will satisfy the equation. If these various combinations of dry and wet bulb temperature are plotted on a psychrometric chart (such as that shown as Fig. 1) it will be found that a straight line can be drawn through all the points; furthermore, this line will pass through the point which represents the room condition. Fig. 2 shows the straight line plotted on a psychrometric chart from Equation 4 for a room condition of 80 F dry bulb, 67 F wet bulb and a sensible heat ratio of 0.85. Notice that the line passes through the point *A* which represents the room condition of 80 F dry bulb and 67 F wet bulb.

It can be shown mathematically that the plot of Equation 4 on a psychrometric chart such as that of Fig. 1 always results in a straight line which passes through the point representing the condition to be maintained in the conditioned room. This fact provides an easy and quick method of determining the many combinations of dry and wet bulb temperatures which an air supply may have and still maintain one definite room condition.[1] If every combination of dry and wet bulb temperatures which results from Equation 4 falls on what will henceforth be called the "sensible heat ratio line," then the determination of these many combinations

[*Concluded on page* 92]

[1]In a monograph published in 1932, the author suggested the method presented here of using the psychrometric chart. This monograph contained a simple table for the rapid solution of Equation 4. However, the use of the psychrometric chart has the advantage of providing a picture of the action taking place, which facilitates reasoning in connection with an air conditioning cycle.

Table 1—Value of Heat Ratio Angle for Various Sensible Heat Ratios

Sensible Heat Ratio	Heat Ratio Angle	Sensible Heat Ratio	Heat Ratio Angle
0.00	90°-0′	0.50	51°-20′
0.02	89°-4′	0.52	49°.5′
0.04	88°-5′	0.54	46°-48′
0.06	87°-5′	0.56	44°-29′
0.08	86°-1′	0.58	42°-9′
0.10	84°-55′	0.60	39°-48′
0.12	83°-46′	0.62	37°-27′
0.14	82°-35′	0.64	35°-7′
0.16	81°-20′	0.66	32°-47′
0.18	80°-2′	0.68	30°-28′
0.20	78°-42′	0.70	28°-11′
0.22	77°-17′	0.72	25°-56′
0.24	75°-49′	0.74	23°-42′
0.26	74°-18′	0.76	21°-33′
0.28	72°-43′	0.78	19°-25′
0.30	71°-4′	0.80	17°-21′
0.32	69°-22′	0.82	15°-21°
0.34	67°-36′	0.84	13°-24′
0.36	65°-46′	0.86	11°-30′
0.38	63°-53′	0.88	9°-41′
0.40	61°-56′	0.90	7°-54′
0.42	59°-55′	0.92	6°-12′
0.44	57°-51′	0.94	4°-34′
0.46	55°-41′	0.96	2°-59′
0.48	53°-33′	0.98	1°-28′
		1.00	0°-0′

Handling Fuel Oil—Part 3

. . calculation of pressure drop, selection of pumping equipment, cost of pumping

By **Kalman Steiner***

THE theoretical horsepower required for overcoming the frictional resistance to the flow of oil, as described in the preceding article of this series,[1] is expressed as a function of gallons per minute pumped (G) and the pressure drop in lb per sq in., $\triangle p$, and specific gravity, s:

$$\text{Theo. } Hp_t = 0.000582\ \triangle pGs \quad \ldots\ldots\ldots\ldots [5]$$

Since neither the pump nor the motor which drives it operate at 100 per cent efficiency, it is necessary to divide the theoretical horsepower by the product of the pump and motor efficiencies to obtain the actual horsepower developed by the motor in overcoming friction through the pipe:

$$Hp_t = \frac{0.000582(\triangle pGs)}{MP} \quad \ldots\ldots\ldots\ldots [6]$$

where M represents motor efficiency and P pump efficiency.

The total horsepower required to transfer a liquid from one point to another is the sum of the power to overcome friction, the power to elevate the liquid from its initial to its final level, and the power to overcome other losses, such as the loss of entrance of the liquid into the pipe and the loss through the pump, etc. This may be expressed as

$$Hp_t = Hp_f + Hp_e + Hp_m \quad \ldots\ldots\ldots\ldots [7]$$

in which Hp_t = total power developed by motor
Hp_f = power required to overcome pipe friction
Hp_e = power required to change liquid level
Hp_m = power required to overcome other losses, such as entrance and pump

Hp_m for the most practical purpose can be taken as 10 per cent of Hp_f; Hp_e is determined from the actual vertical distance between the original and final liquid levels, and is numerically equal to $\frac{0.00025\ esG}{MP}$, e being difference in liquid levels in feet. Hence the complete expression for total horsepower developed can be written as a function of gallons per minute, G, specific gravity (no units) s, with e, M, and P, as above:

$$Hp_t = \frac{Gs}{MP}\left[\ 0.00064\ (\triangle p) + 0.00025\ (e)\ \right] \quad \ldots\ldots\ldots\ldots [8]$$

The application of these formulas is best illustrated by working out a few typical problems.

Problem 1—A railroad tank car holding 10,000 gal of fuel oil is to be unloaded at a rate of 300 gpm through a pump and 3 in. pipe line into a vertical storage tank whose capacity is 2000 gal per vertical foot. The fuel oil has an *API* gravity of 17 deg and a viscosity of 900 Saybolt Universal Seconds at the pumping temperature. The pump efficiency is 55 per cent, and the motor efficiency 75 per cent. Find the cost of electrical power at the rate of 3c per kw-hr for unloading the car under the stated conditions, the various elevations and distances being as shown in the sketch.

Solution: From the table published in December,[1] $s = 0.95$ and $Z = 188$. From Fig. 3 (in December), or by Equation 2, $V = 13$. Hence the modulus $DVs/Z = (3.07 \times 13 \times 0.95)/188 = 0.203$. By referring to Fig. 2 (December) it is noted, first, that the flow is turbulent, and second, that the corresponding value of f is 0.015. Substituting in Equation 4,[1]

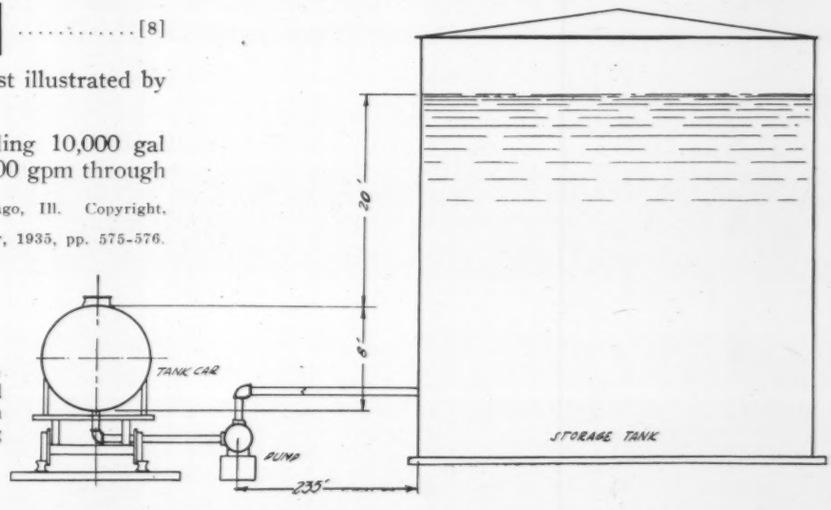
$$\triangle p = 0.323 \times \frac{0.015 \times 0.95 \times 235 \times 13 \times 13}{3.07} = 59.5 \text{ lb per sq in.}$$

At the start of pumping, the difference in liquid level is 20 ft. At the end, the tank level is 5 ft higher and the car level 8 ft lower than at the start, making a total difference of 33 ft in liquid level when the pumping is finished. The average difference in liquid level is therefore 26.5 ft, and this value may be used for e. The power expended in pumping is, by Equation 8,

$$Hp_t = \frac{300 \times 0.95}{0.75 \times 0.55}\left[\ 0.00064 \times 59.5 + 0.00025 \times 26.5\ \right] = 30.6$$

The total time for unloading the car is 10,000/300, or 33.3 minutes. The energy expended for unloading is $33.3/60 \times 30.6 \times 0.746 = 12.7$ kw-hr. At 3 cents per kw-hr, the power cost is 38.1 cents.

Problem 2—Fuel oil is to be drawn from storage and



Cost of power for unloading the tank car pictured is calculated in Problem 1, as is the time in minutes required for unloading

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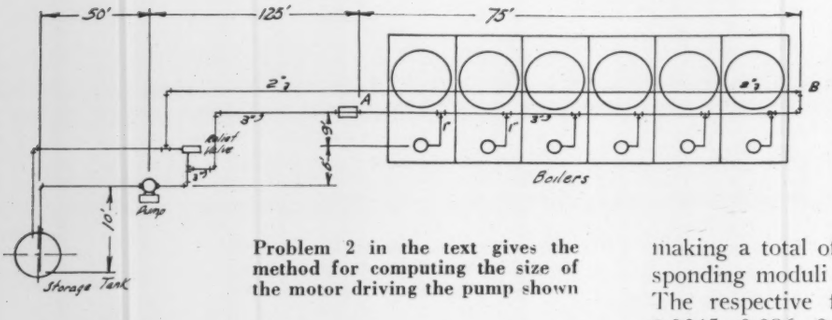
[1] HEATING, PIPING AND AIR CONDITIONING, December, 1935, pp. 575-576.



Problem 2 in the text gives the method for computing the size of the motor driving the pump shown

delivered to a battery of six oil fired boilers, each developing 1000 boiler hp. Oil in the storage tank has an *API* gravity of 8 and a Saybolt Universal viscosity of 3000 at 100 F, which temperature is maintained in the tanks by heating coils. At the point *A* shown in the diagram, a preheater raises the oil temperature and reduces the oil viscosity to 415 Saybolt seconds, the gravity changing to 14 *API*. The fuel has a calorific value of 156,000 Btu per gal, and is burned at an efficiency of 70 per cent. Hydraulic losses through fittings are taken as 30 diameters for ells and 90 for tees. If the pump efficiency is 45 per cent, calculate the size of electric motor required for the pump, allowing a return to storage of one-third.

Solution: A boiler hp is defined as 33,500 Btu per hr. The total fuel burned is therefore (33,500 × 6000)/(0.7 × 156,000), or 1840 gph. Add one-third this amount for oil bypassed back to tank, and the quantity of oil pumped is 2450 gph or 41 gpm. Hence the rates of flow through the various sizes of pipe, and the respective velocities are: 3 in. pipe, 41 gpm and 1.76 ft per sec; 2 in. pipe, 10 gpm and 0.95 ft per sec; 1 in. pipe, 5.1 gpm and 1.87 ft per sec.

From the table published in December,[1] the initial specific gravity and centipoises are $s = 1.01$ and $Z = 667$. At the preheater, near the boilers, these values become, respectively, 0.97 and 87.6. The total equivalent length of 3 in. pipe between the pump and point *A*, allowing for 3 ells and 1 tee, is 183 ft. From the heater to the end of the feed header, point *B*, including the 2 ells and 6 tees, the equivalent pipe length is 110 ft. The length of return line is figured back to the pump at 214 ft, and the length of each feed line from the header down to each burner regulating valve is 9 ft, making a total of 54 ft for the six burners. The corresponding moduli are 0.0082, 0.0598, 0.0218, and 0.0217. The respective friction factors are accordingly 0.252, 0.0345, 0.096, 0.096. It is now necessary to perform four separate calculations of pressure drop with Equation 4:

$$\Delta p_1 = 0.323 \times \frac{0.252 \times 1.01 \times 183 \times 1.76 \times 1.76}{3.07} = 15.6$$

$$\Delta p_2 = 0.323 \times \frac{0.0345 \times 0.97 \times 110 \times 1.76 \times 1.76}{3.07} = 1.2$$

$$\Delta p_3 = 0.323 \times \frac{0.096 \times 0.97 \times 214 \times 0.95 \times 0.95}{2.07} = 2.81$$

$$\Delta p_4 = 0.323 \times \frac{0.096 \times 0.97 \times 54 \times 1.87 \times 1.87}{1.05} = 5.41$$

Total pressure drop = 25.02 lb per sq in.

Calculation of the power losses in these four sections of pipe is made by four applications of Equation 8, except that the efficiency factor for the pump is introduced at the end. Taking the above pressure drops in succession,

$$Hp_1 = 41 \times 1.01 \times (0.00064 \times 15.6 + 0.00025 \times 15) = 0.572$$
$$Hp_2 = 41 \times 0.97 \times (0.00064 \times 1.2 + 0.00025 \times 0) = 0.031$$
$$Hp_3 = 10 \times 0.97 \times (0.00064 \times 2.81 + 0.00025 \times -25) = -0.044$$
$$Hp_4 = 5.1 \times 0.97 \times (0.00064 \times 5.41 + 0.00025 \times 9) = 0.006$$

Total theoretical hp required = 0.565

Dividing by the pump efficiency gives the motor size required as 0.565/0.45, or 1.25 hp.

[Succeeding articles will cover pressure regulation, strainers, metering, and control.—The Editor.]

Psychrometric Chart—

[*Continued from page* 90]

resolves itself into the simple problem of locating this one line on the psychrometric chart.

However, simply knowing that the plot of Equation 4 is a straight line is not sufficient to locate the line on the psychrometric chart. In addition to knowing that the line passes through the point representing the room condition, the inclination of the line with the horizontal, or, as it is usually called, the slope, must be known as well. However, it can also be shown mathematically that the slope of the heat ratio line is determined only by the sensible heat ratio. Regardless of all other considerations, once the sensible heat ratio is known, the heat ratio line can be drawn.

Table 1 gives values of the angle which the heat ratio line makes with the horizontal for various values of the sensible heat ratio; these angles will henceforth be called the "heat ratio angles." Fig. 3 illustrates how these angles are measured on the psychrometric chart. The center of a protractor is laid on the psychrometric chart at the point *A* representing the room condition. The heat ratio angle is measured from the horizontal line passing through the point *A*. The horizontal line passing through the point *A*, is, of course, the dew point temperature of the conditioned room.

In Fig. 3, two heat ratio lines are shown drawn through a room condition of 75 F dry bulb and 50 per cent relative humidity. One line is for a sensible heat ratio of 0.90; that is, 90 per cent of the total heat gain of the room is sensible. The second line is for a sensible heat ratio of 0.70. Naturally the 0.70 line is steeper than the 0.90 line since more latent heat must be absorbed by the air supply when the sensible heat gain in the conditioned room is 70 per cent of the total than when it is 90 per cent. Inspection of the two heat ratio lines shows that for the same dry bulb temperatures the dew point temperature of the air supply for the 70 per cent condition must be lower than for the 90 per cent condition.

[Next month, the solution of typical problems by this method will be shown.—Editor.]

DESIGN OF MODERN INDUSTRIAL PIPING SYSTEMS

THE SUPPORT OF PIPE LINES

By **F. L. Snyder*** ***and*** **T. E. Bridge†**

Considering the structure supporting an industrial pipe line as an integral part of the piping system, the authors present here methods which have been found by application in daily plant piping design work to be practical, efficient, and economical...Design data are presented in chart and table form, and their uses are explained with examples

THE structure supporting a pipe line is considered an integral part of the piping system and is given such consideration in the following discussion. The authors have confined their efforts to presenting a simple method for determining the location of pipe supports. In a later issue, determination of the size of the support will be discussed.

The methods here described have been found by application to be practical, efficient and economical. In many instances where piping is transporting a fluid having a temperature greater than atmospheric, preference is given to hanging the pipe from, rather than supporting the pipe on, the support. This method is believed to have a decided advantage, since the deflection of the pipe due to thermal expansion can be more readily concentrated at the anchor points, thus relieving the supporting structure from this force. The slightly increased weight of structural components due to eccentricity of loading is more than compensated for in the cost of ball bearing rollers and guides, which are recommended instead of the ordinary roller. When pipe is supported on ordinary rollers and without guides, it is important that consideration be given the friction load, and the possibility of the pipe displacing itself on the rollers. If this is carefully considered it will be found that very little if any economy can be gained by the use of ordinary rollers.

If the pipe is not subjected to temperatures higher than atmosphere, it may then be of advantage to support the pipe directly on the structure. In this case the pipe is considered to be a continuous beam between the supporting columns and may be supported without the use of rollers, but with an ordinary "U" bolt or pipe chair. With this method the weight of the supporting structure is considerably reduced. When this arrangement is used it is obvious that the normal expansion thrust due to atmospheric changes must be considered.

When pipe is hung from the support as shown in Fig. 1, provision should be made for movement in any direction. The hanger rod, either stationary or swing type, should be designed to give minimum resistance to movement. If the stationary type is used the length should be sufficient to reduce the bending moment of the rod due to lateral movement of the pipe. Fig. 3 shows suggested designs for pipe hangers together with leading dimensions of component parts.

Design of Spring Hangers

Where thermal deflection of the pipe line is to be absorbed in a direction change such as shown in Fig. 2, spring hangers are suggested. In this case the spring hanger should be designed to support the pipe in the deflected position to relieve the pipe of unnecessary strains due to dead load deflection. Table 1 will simplify the selection of the proper spring; these data are compiled from A. M. Wahl's article in *A. S. M. E.* "Applied Mechanics," March, 1935, in which it is stated that

$$P = d^3S / 5.093rK$$

where

P = Safe load capacity of spring
S = Fibre stress in lb per sq in.
$K = (4C - 1) / (4C - 4) + (0.615 / C)$

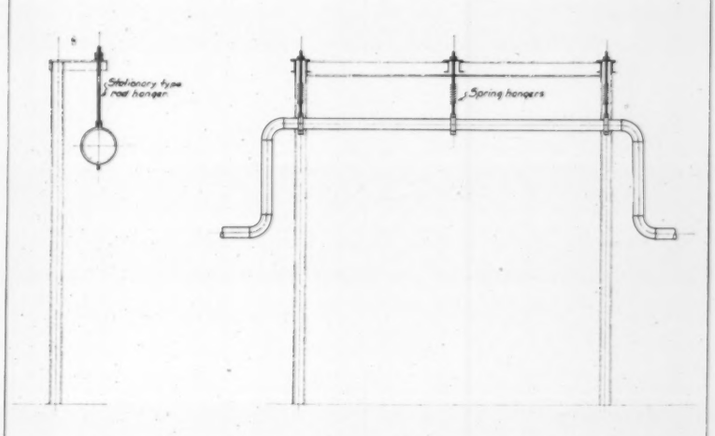


Fig. 1 (*left*)—Stationary type rod hanger. Fig. 2 (*right*) Where thermal deflection of the line is to be absorbed in a direction change, spring hangers are suggested

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Table 1—Data for Spring Design

Diam. of spring wire		MEAN DIAMETER OF SPRING																																		
		1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½	9	9½	10
1/8	P	45	37	32	28	24																														
	Δ	.129	.208	.31	.431	.55																														
	Δ1	.2875	.562	.968	1.54	2.3																														
3/16	P	140	117	101	88	79	71																													
	Δ	.08	.13	.194	.267	.359	.46																													
	Δ1	.057	.11	.192	.303	.455	.648																													
1/4	P	302	259	226	200	179	162	148	136																											
	Δ	.0542	.0872	.137	.1925	.2575	.352	.416	.508																											
	Δ1	.018	.0337	.0606	.096	.144	.205	.283	.374																											
5/16	P		472	417	372	335	305	280	258	240																										
	Δ		.0677	.1036	.1465	.197	.256	.322	.395	.477																										
	Δ1		.0143	.0248	.0394	.0588	.084	.115	.153	.198																										
3/8	P			680	615	557	507	467	433	404	377	354	333																							
	Δ			.0815	.117	.158	.205	.259	.32	.387	.458	.54	.623																							
	Δ1			.012	.019	.0784	.0404	.0555	.074	.096	.1215	.1525	.187																							
7/16	P				928	850	780	718	670	625	585	550	525	491	467																					
	Δ				.0955	.13	.1705	.215	.267	.324	.385	.453	.53	.603	.687																					
	Δ1				.0103	.0153	.0219	.0299	.04	.0518	.0658	.0824	.101	.1228	.147																					
1/2	P					1210	1120	1038	965	905	850	802	758	718	680	648	620																			
	Δ					.1085	.1432	.182	.2255	.274	.327	.386	.448	.516	.586	.662	.746																			
	Δ1					.009	.0128	.0175	.0234	.0303	.0385	.0482	.0592	.072	.0863	.102	.1205																			
9/16	P						1530	1430	1338	1250	1180	1110	1050	1000	950	908	868	832	795																
	Δ						.1221	.156	.1945	.236	.283	.334	.387	.448	.508	.578	.651	.728	.805																	
	Δ1						.008	.0109	.0146	.0189	.024	.0301	.0368	.0448	.0535	.0636	.075	.0875	.1012																	
5/8	P							1892	1775	1670	1570	1490	1412	1347	1282	1225	1171	1122	1080	1038	997													
	Δ							.1357	.1695	.207	.2475	.294	.342	.396	.4525	.513	.578	.645	.718	.793	.872													
	Δ1							.0072	.01	.0124	.0158	.0197	.0242	.0294	.0353	.0418	.0493	.0524	.0665	.0765	.0875													
11/16	P								2280	2160	2035	1935	1833	1753	1670	1595	1530	1467	1408	1355	1303	1260	1218											
	Δ								.149	.183	.219	.261	.304	.353	.403	.457	.516	.577	.639	.709	.778	.855	.935											
	Δ1								.0065	.0085	.0108	.0135	.0167	.0215	.0242	.0286	.0338	.0394	.0455	.0523	.0597	.0678	.0768											
3/4	P									2722	2580	2460	2336	2235	2135	2030	1946	1866	1785	1730	1670	1615	1557	1510	1471									
	Δ									.163	.1962	.2336	.2725	.317	.3635	.41	.463	.5175	.572	.638	.703	.773	.842	.92	1.003									
	Δ1									.006	.008	.0095	.0117	.0142	.0174	.0202	.0238	.0277	.0321	.0369	.0422	.0478	.0541	.061	.0683									
13/16	P										3190	3045	2902	2765	2650	2535	2430	2340	2260	2170	2100	2025	1955	1895	1834	1780	1729							
	Δ										.176	.2102	.246	.285	.3275	.372	.42	.471	.526	.582	.642	.705	.768	.839	.91	.983	1.06							
	Δ1										.005	.0069	.0085	.0103	.0124	.0147	.0173	.0202	.0233	.0268	.0306	.0348	.0393	.0443	.0496	.0553	.0613							
7/8	P											3645	3500	3330	3200	3065	2950	2825	2720	2625	2535	2460	2370	2303	2238	2170	2098	2040	1975						
	Δ											.187	.221	.255	.294	.334	.378	.423	.471	.523	.576	.635	.692	.758	.824	.89	.955	1.029	1.1						
	Δ1											.0051	.0063	.0077	.0092	.0109	.0128	.0149	.0173	.0199	.0228	.0258	.0292	.0329	.0368	.041	.0455	.0505	.0557						
15/16	P												4250	4090	3920	3750	3610	3490	3330	3235	3115	3020	2920	2840	2757	2665	2600	2525	2452	2385	2335				
	Δ												.2038	.236	.274	.3105	.352	.397	.438	.489	.538	.593	.648	.708	.77	.851	.901	.97	1.038	1.105	1.192				
	Δ1												.0048	.0058	.0069	.0083	.0097	.0114	.0132	.0151	.0173	.0196	.0222	.0249	.0279	.0319	.0346	.0384	.0423	.0463	.0511				
1	P													4850	4635	4475	4310	4150	4000	3860	3735	3618	3505	3400	3290	3200	3120	3040	2965	2880	2810	2730	2600			
	Δ													.2177	.2495	.286	.3225	.3645	.406	.45	.566	.598	.601	.655	.711	.769	.834	.901	.968	1.033	1.108	1.18	1.33			
	Δ1													.0045	.0054	.0064	.0075	.0088	.0103	.0117	.0152	.0165	.0172	.0193	.0216	.024	.0267	.0296	.0326	.0359	.0394	.0431	.0512			
1 1/16	P														5460	5250	5080	4800	4720	4540	4420	4250	4140	4002	3910	3800	3675	3583	3490	3410	3340	3260	3090	2950	2825	
	Δ														.231	.263	.298	.33	.375	.416	.461	.505	.556	.607	.661	.717	.771	.833	.895	.962	1.03	1.1	1.24	1.395	1.555	
	Δ1														.0042	.005	.0059	.0068	.0079	.0092	.0104	.0119	.0134	.0151	.0169	.0189	.021	.0232	.0256	.0282	.0308	.0337	.0402	.0473	.055	
1 1/8	P															5680	5485	5310	5090	4960	4790	4640	4490	4375	4250	4125	4020	3900	3800	3715	3630	3540	3382	3215	3090	
	Δ															.2765	.2575	.291	.3225	.362	.398	.438	.48	.526	.573	.62	.672	.721	.775	.823	.895	.953	1.08	1.21	1.352	
	Δ1															.004	.0047	.0055	.0063	.0073	.0089	.0095	.0107	.012	.0135	.0152	.0167	.0185	.0204	.0224	.0247	.027	.0319	.0376	.0438	

Values between the heavy lines are within the "C" value range.

P = Safe carrying capacity of spring in pounds.
Δ = Deflection in inches of one coil under safe load.
Δ1 = Deflection in inches per 100 lbs. of load.

The above springs are designed with a fibre stress of 69000#/□". For any other other stress proceed as described on attached sheets.

$C = 2r / d$ (For round wire)
d = Diameter of round bar spring wire, in inches
r = Mean radius of coil in inches

It will be noted that the safe carrying capacity of the springs shown in the table is based on a fibre stress of 69,000 lb per sq in. This has been found to be a good general value for all sizes of springs when used for supporting pipes. However, if any other value of stress is desirable, proceed as described in the following example:—

Assume a 5 in. mean diameter spring constructed of 1 in. diameter wire. As shown in the table this spring will carry a safe load of 4150 lb, and each coil will deflect 0.3645 in. The spring when designed with a stress of 50,000 lb per sq in. will support a load of 3010 lb or $50{,}000 \times 4150 / 69{,}000 = 3010$ lb, and each coil will deflect $50{,}000 \times 0.3645 / 69{,}000 = 0.2645$ in. The springs shown in the table are designed with round bar spring wire.

Distance Between Supports

In determining the distance between pipe supports consideration must be given to (a) The fibre stress created in the pipe walls due to internal pressure. (b) The fibre stress created in the pipe walls due to dead load deflection. The stresses in the pipe wall due to internal pressure combine at right angles to the bending stress. However, the complete and accurate solution of the true resultant stresses set up from this combination of bending and bursting, is complex and beyond the scope of this paper. For practical purposes these stresses are assumed to add arithmetically. This, incidentally, introduces a safe margin.

In order to simplify the work necessary to determine these values, nomographic charts Figs. 4 and 5 were constructed. Fig. 4 is based on the fundamental beam formula

$$\Delta = 5WL^4 / 384EI$$
$$S = WL^2y / 8I \text{ or } WL^2 / 8Z$$

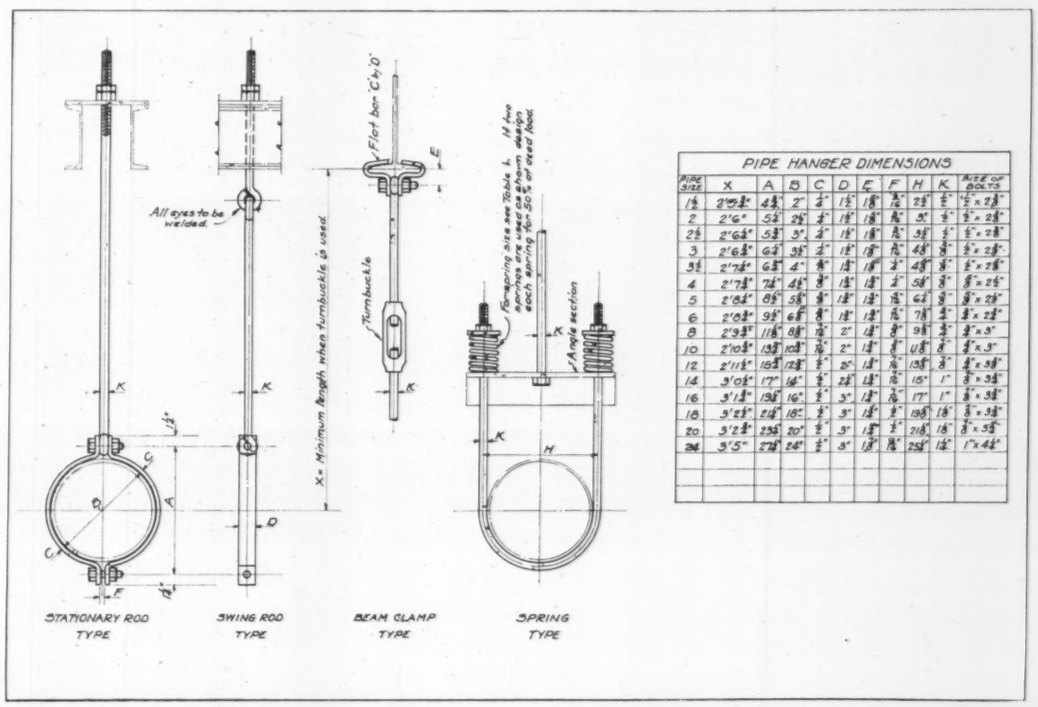
where

D = Nominal diameter of pipe in inches
Δ = Greatest deflection of the pipe between supports
W = Weight of the pipe in lb per lineal in. including weight of contents, insulation and ice if any
L = Length of pipe between supports in inches
E = Modulus of elasticity of the pipe material at the working temperature shown on Fig. 6
I = Moment of inertia of the cross section of the pipe, shown in Table 2
S = Fibre stress in lb per sq in. on the most strained fibre of the pipe material at the working temperature shown on Fig. 6
y = Distance from neutral axis of pipe to the most distant fibre in inches, or the outside diameter of the pipe as shown in Table 2 divided by 2
Z = Section modulus I/y as shown in Table 2

It will be noted that the formula used to construct Fig. 4 is expressed as $\Delta = 5 \times 1728 \times WL^4 / 384EI$, and $S = 12 \times WL^2 / 8Z$. This permits the length and weight of the pipe to be referred to in foot units rather than inch units as expressed in the fundamental formula.

This formula assumes that the pipe is hinged at each support. Actually, the pipe in most cases is rigidly supported, but since the positive reactions that exist at each support are not known, it has been found advisable to assume the pipe supported freely and without bending. This of course, is the extreme case. If the pipe were restrained at the supports, the stress and deflection would be considerably reduced. Therefore, a very definite safety factor exists in Fig. 4.

Fig. 5 is based on the *A. S. M. E.* power piping code formula for determining fibre stresses in pipe walls due to internal pressure and is expressed


All eyes to be welded.
Flat bar 'C' by 'D'
Turnbuckle
X= Minimum length when turnbuckle is used.
For spring sizes see Table 4. If two springs are used add 50% to each spring for 50% of dead load.
Angle section
STATIONARY ROD TYPE
SWING ROD TYPE
BEAM CLAMP TYPE
SPRING TYPE

PIPE HANGER DIMENSIONS

PIPE SIZE	X	A	B	C	D	E	F	H	K	SIZE OF BOLTS
1½	2'-5¾"	4¾"	2"	¼"	1½"	1⅜"	⅝"	2½"	½"	½" x 2½"
2	2'-6"	5¼"	2½"	¼"	1½"	1⅜"	⅝"	3"	½"	½" x 2½"
2½	2'-6½"	5⅜"	3"	¼"	1½"	1⅜"	⅝"	3½"	½"	½" x 2½"
3	2'-6⅝"	6¼"	3⅝"	¼"	1½"	1⅜"	⅝"	4⅜"	⅝"	⅝" x 2½"
3½	2'-7⅛"	6⅜"	4"	⅜"	1½"	1⅜"	⅝"	4⅜"	⅝"	⅝" x 2½"
4	2'-7⅜"	7¼"	4⅝"	⅜"	1½"	1⅜"	⅝"	5⅛"	⅝"	⅝" x 2½"
5	2'-8¼"	8⅝"	5⅝"	⅜"	1½"	1⅜"	⅝"	6¼"	⅝"	⅝" x 2½"
6	2'-9⅜"	9⅝"	6⅝"	⅜"	1½"	1⅜"	⅝"	7⅛"	⅝"	⅝" x 2½"
8	2'-9⅞"	11⅝"	8⅝"	½"	2"	1⅝"	⅞"	9⅛"	⅝"	⅞" x 3"
10	2'-10⅝"	13⅞"	10⅜"	½"	2"	1⅝"	⅞"	10⅛"	⅞"	⅞" x 3"
12	2'-11⅝"	16⅛"	12⅝"	½"	2½"	1⅝"	1"	13⅝"	⅞"	⅞" x 3½"
14	3'-0⅝"	17"	16"	½"	2½"	1⅝"	1"	15"	1"	⅞" x 3½"
16	3'-1⅜"	19⅛"	16"	½"	3"	1⅝"	1"	17"	1"	⅞" x 3½"
18	3'-2⅝"	21⅛"	18"	½"	3"	1⅝"	1"	19⅛"	1⅛"	⅞" x 3½"
20	3'-3⅝"	23⅛"	20"	½"	3"	1⅝"	1"	21⅛"	1⅛"	⅞" x 5½"
24	3'-5"	27⅛"	24"	½"	3"	1⅝"	1⅛"	25⅛"	1¼"	1" x 4½"

Fig. 3—Suggested designs and dimensions for pipe hangers

Table 2—Properties of Pipe

NOMINAL PIPE SIZE	EXTERNAL DIAMETER INCHES	INTERNAL DIAMETER INCHES	THICKNESS OF WALLS INCHES	WEIGHT PER FOOT LBS.	WEIGHT OF WATER IN ONE FOOT OF PIPE LBS.	SQ. FT. OF EXTERNAL SURFACE PER FOOT OF PIPE.	SQ. FT. OF INTERNAL SURFACE PER FOOT OF PIPE.	TRANSVERSE AREA IN SQ. IN. "A"	AREA OF METAL IN SQ. IN. "A"	MOMENT OF INERTIA "I"	SECTION MODULUS "Z"	RADIUS OF GYRATION "R"	RADIUS OF GYRATION "R"	ULTIMATE BURSTING PRESSURE. BUTT-WELD FIBRE STRESS-40000 LBS.	ULTIMATE BURSTING PRESSURE. LAP-WELD FIBRE STRESS-35000 LBS.	ULTIMATE BURSTING PRESSURE. HAMMER-WELD FIBRE STRESS-45000 LBS.	ULTIMATE BURSTING PRESSURE. SEAMLESS FIBRE STRESS-60000 LBS.	STRENGTH FACTOR "Q"
1/8	.405	.269	.068	.244	.0245	.106	.0694	.05663	.07199	.001064	.005252	.01477	.1215	11435			14903	.01182
		.215	.095	.314	.0157		.0563	.03632	.09245	.001207	.006804	.01914	.1145	10763			14027	.01111
1/4	.540	.364	.088	.424	.0451	.139	.0939	.1041	.133	.003314	.01227	.01621	.1628	10237			13614	.02160
		.302	.119	.535	.0310		.0776	.07163	.1874	.003764	.01395	.01999	.1567	17630			25186	.03138
3/8	.675	.493	.091	.567	.0638	.180	.1187	.1472	.1870	.007139	.02160	.03567	.2090	10765			18401	.04860
		.423	.126	.738	.0929		.1090	.1405	.2578	.008619	.02604	.03344	.1897	14093			21781	.05760
1/2	.840	.622	.109	.850	.1316	.221	.1637	.304	.3569	.01769	.04069	.06858	.2673	10387			14850	.09156
		.546	.147	1.087	.1013		.1493	.234	.3200	.02000	.04700	.06773	.2506	14000			20000	.10760
		.252	.294	1.714	.0216		.0634	.04987	.5043	.01624	.05772	.04807	.2192	25000			40000	.17390
3/4	1.050	.824	.113	1.131	.2977		.2765	.5333	.5796	.03764	.07055	.1113	.3937	15000			24000	.12960
		.742	.154	1.473	.1875	278	.1940	.433	.4330	.04479	.08537	.1093	.3214	11783			16761	.19190
		.2150	.1815	1.777	.1545		.1759	.357	.5081	.04349	.09427	.09740	.3121	14286			20408	.21210
		.634	.508	1.440	.2633		.1228	.1419	.7510	.05219	.1103	.08068	.2840	23571			33524	.24870
1	1.315	1.049	.133	1.679	.3742	.344	.2749	.864	.8740	.1109	.1688	.1769	.3560	14093			20133	.27560
		.957	.179	2.171	.3112		.2494	.719	.6388	.1056	.1606	.1653	.4066	10890			15557	.36140
		.8775	.2175	2.561	.3614		.2390	.604	.7534	.1177	.1790	.1562	.3952	13307			19010	.40250
		.799	.258	2.939	.4121		.2291	.501	.8647	.1291	.1964	.1505	.3813	15911			911	.44070
1¼	1.660	1.380	.140	2.273	.6471		.3400	.1495	.6685	.1947	.2346	.2913	.5397	6747	8432		10123	.27000
		1.278	.191	2.996	.5553	434	.3346	.1283	.8815	.2410	.2913	.2743	.5737	9205	11506		14258	.45850
		1.160	.250	3.764	.4375		.3039	.1057	1.070	.2839	.3421	.2565	.5063	12045	15058		18818	.76960
		.896	.382	4.714	.2977		.2333	.4305	1.362	.3441	.4110	.2224	.4716	18410	23012		28766	.92410
1½	1.900	1.610	.145	3.174	.9018		.4970	.2035	1.225	.3826	.4026	.3124	.5724	10161	12701		15876	.52230
		1.500	.200	3.631	.7648	499	.3927	.1767	1.068	.3912	.4118	.3665	.5652	8421	10527		13160	.97650
		1.3375	.2815	4.862	.6082		.3571	.1405	1.430	.4826	.5080	.3375	.5809	11042	13803		18504	.11490
		1.100	.400	6.408	.4117		.2880	.0950	1.811	.5678	.5977	.3013	.5469	16861	21076		26316	.13450
2	2.375	2.067	.154	5.022	.1.452		.6211	.3357	3.355	.9621	1.009	.6196	.7011	8185	10231		12760	.31410
		2.041	.167	5.938	1.420		.6360	.3270	3.558	1.018	1.068	.6179	.6819	9475	11837		14790	.31450
		2.000	.1875	6.686	1.363	622	.6283	.3142	3.769	1.064	1.116	.6025	.6662	10316	12895		16119	.31470
		1.939	.250	8.678	1.279		.6075	.2956	4.430	1.174	1.232	.5870	.6435	13441	16801		21001	.31440
		1.875	.250	9.113	1.196		.5795	.2761	4.669	1.232	1.293	.5646	.6221	14171	17714		22142	.31450
		1.750	.3125	10.889	1.041		.5498	.2405	5.275	1.392	1.462	.5442	.6036	16896	21120		26400	.31480
		1.503	.436	14.389	.7686		.4723	.1774	6.492	1.711	1.796	.5227	.5827	20756	25945		32431	.31490
2½	2.875	2.469	.203	7.661	2.072		.7756	.4788	5.845	1.530	2.132	.7042	.7834	8416	10520		13150	.31940
		2.441	.217	8.160	2.026		.7668	.4680	5.977	1.611	2.245	.6890	.7716	8638	10798		13497	.31940
		2.323	.276	9.621	1.834	753	.7298	.4236	6.569	1.914	2.669	.6539	.7577	9830	12288		15360	.31970
		2.125	.375	12.017	1.535		.6676	.3547	7.547	2.165	3.018	.5993	.7347	12435	15544		19430	.32000
		1.771	.552	16.101	1.067		.5564	.2463	8.846	2.353	3.282	.5446	.7156	17243	21554		26943	.32020
3	3.500	3.068	.216	9.253	3.200		.9017	.7393	7.393	3.071	3.774	1.354	1.166	4991	6171		7714	.3.8790
		3.018	.241	10.133	3.097		.8895	.7155	7.967	3.194	3.882	1.335	1.155	5509	6886		8601	.42350
		2.900	.300	12.177	2.859	.916	.8569	.6605	8.516	3.516	4.264	1.285	1.134	6837	8547		10684	.42010
		2.771	.364	14.483	2.689		.8253	.6026	9.091	3.817	4.615	1.237	1.113	8328	10410		13012	.41960
		2.625	.4375	17.022	2.456		.7872	.5413	9.731	4.131	5.000	1.189	1.090	9984	12480		15600	.41900
		2.300	.600	22.850	1.800		.6913	.4155	11.146	4.788	5.793	1.093	1.047	13801	17143		21429	.41950
3½	4.000	3.548	.226	10.790	4.279		.9296	.9886	9.887	4.788	5.936	1.789	1.337	4520	5650		7063	.5.3060
		3.438	.281	13.358	4.017		.9000	.9281	10.296	4.979	6.216	1.735	1.318	5525	6906		8632	.5.2990
		3.364	.318	15.005	3.847	1.047	.8796	.8888	10.678	5.160	6.450	1.700	1.307	6240	7950		9938	.7065
		3.152	.4375	20.012	3.380		.8253	.7803	11.882	5.743	7.180	1.607	1.268	8275	8894		10742	.7490
		3.000	.500	22.850	3.186		.7854	.7163	12.566	6.072	7.584	1.536	1.239	9515			14446	.9781
		2.900	.600	27.040	2.962		.7593	.6605	13.179	6.368	7.960	1.472	1.210	12120	15900		19875	.9760
4	4.500	4.026	.237	12.730	5.510		1.055	12.730	12.730	7.114	8.233	2.214	1.559		5267		6583	.7233
		3.939	.2815	15.172	5.269		1.031	12.174	12.174	8.332	8.703	2.155	1.495		6250		7812	.8332
		3.826	.337	18.043	4.976	1.178	1.002	11.497	11.497	8.407	9.610	2.093	1.477		7489		9361	.9610
		3.624	.438	23.271	4.465		.9487	10.315	10.315	8.988	10.476	1.979	1.447		8353		10441	10490
		3.500	.500	26.360	4.164		.9163	.9621	9.621	9.283	11.770	1.917	1.425		9.1112		13890	12.110
		3.438	.531	27.841	3.980		.8962	.9281	9.101	9.180	11.948	1.884	1.414		9570		11962	12.280
4½	5.000	4.813	.237	14.324	6.508		.9852	.9084	9.084	9.283	11.588	2.279	1.510		10.1112		12.1112	12.280
		4.813	.237	14.324	6.508		1.181	18.194	18.194	9.283	11.588	2.279	1.510		10.1112		12.1112	12.280
		4.750	.250	15.063	6.394		1.161	17.721	17.721	9.420	11.764	2.313	1.505		9.1112		12.1112	12.280
		4.700	.275	16.562	6.269		1.125	17.349	17.349	9.530	11.941	2.342	1.501		9.1112		12.1112	12.280
		4.624	.313	18.818	6.062		1.085	16.780	16.780	9.714	12.233	2.394	1.496		9.1112		12.1112	12.280
		4.500	.375	22.517	5.729	1.309	1.032	15.904	15.904	9.933	12.500	2.450	1.490		9.1112		12.1112	12.280
		4.313	.469	28.044	5.269		.9708	14.610	14.610	10.161	12.774	2.503	1.484		9.1112		12.1112	12.280
		4.063	.562	33.434	4.852		.9143	12.966	12.966	10.290	12.952	2.537	1.472		9.1112		12.1112	12.280
		4.000	.600	35.650	4.701		.9000	12.566	12.566	10.296	12.960	2.537	1.472		9.1112		12.1112	12.280
5	5.563	5.047	.258	18.974	8.659		1.321	20.006	20.006	15.160	19.435	3.326	1.878		8230		9876	12.260
		4.859	.352	25.590	8.026		1.272	18.547	18.547	15.968	20.464	3.502	1.860		8127		9752	12.830
		4.813	.375	27.179	7.815		1.260	18.194	18.194	16.112	20.670	3.531	1.853		8231		9877	12.810
		4.688	.4375	33.383	7.472	1.436	1.227	17.262	17.262	16.645	21.350	3.648	1.839		8565		10278	12.890
		4.313	.625	47.961	6.324		1.129	14.610	14.610	17.696	22.693	3.878	1.800		9.1112		12.1112	12.290
		4.063	.750	58.551	5.617		1.064	12.966	12.966	18.290	23.460	4.009	1.777		9.1112		12.1112	12.290
6	6.625	6.065	.280	28.573	12.51		1.737	28.890	28.890	28.151	34.084	5.044	1.945		6.1112		7.1112	19.120
		5.761	.432	28.573	11.29	1.735	1.510	26.070	26.070	8.408	40.490	2.770	4.817	2.195			6721	27.500
		5.501	.562	53.160	9.14		1.280	18.890	18.890	15.640	66.380	10.020	4.741	2.060			16502	45.000
		5.189	.7188	63.246	16.78		1.84	58.140	58.140	6.996	66.820	11.200	6.716	2.393			8395	32.650
7	7.625	7.001	.312	25.548	16.28	1.996	2.188	38.484	38.484	41.54	52.77	8.772	6.377	2.525			11.1112	43.000
		6.815	.875	63.079	11.74		1.850	32.110	18.560	101.90	70.180	8.791	7.406				11.1112	43.000
8	8.625	8.071	.277	24.696	22.16		2.115	51.160		7.265	63.35	14.690	8.731	2.953			3212	38.050
		7.981	.322	28.554	21.65		2.090	50.027		8.398	72.69	16.810	8.690	2.939			4486	37.820
		7.813	.406	35.875	20.602		2.045	47.946		10.230	88.53	20.480	8.651	2.918			5981	37.690
		7.625	.500	43.388	19.77	2.258	2.013	46.415		12.010	100.42	23.780	8.960	2.889			5435	52.790
		7.437	.594	50.877	18.49		2.006	45.663		12.760	105.70	24.510	8.783	2.878			5797	55.160
		7.375	.625	53.400	18.49		1.931	42.720		15.710	126.50	29.330	8.652	2.837			7024	68.000
		7.188	.719	61.584	17.80		1.868	40.589		16.170	130.40	30.240	8.604	2.821			7236	68.900
9	9.625	9.561	.342	33.907	27.20		2.340	22.719	9.914		107.60	22.350	10.790	3.284			3359	44.1.50.300
		9.375	.500	48.728	25.31	2.520	2.258	58.43	14.330		149.60	31.090	10.440	3.231			5185	6493 69.960
		9.189	.718	68.556	24.18		2.006	46.66	21.100		155.50	32.310	10.260	3.070			10.3589	11.1986 119.600
		9.063	.781	74.700	23.54		1.949	45.60	19.350		151.90	33.400	10.130	3.703			10.3589	11.1986 119.600
		20.196	.179	36.240	34.96		2.669	80.69	10.070		37.40	25.570	19.680	3.694			2856	35.710 51.210
		20.000	.365	70.685	34.13		2.622	78.855	11.910		160.70	29.900	18.500	3.674			3393	42.441 62.180
		19.750	.395	76.484	33.12		2.610	77.800	12.850		172.50	32.090	18.420	3.666			3760	47.001 72.300
10	10.75	10.420	.165	34.240	29.60	2.814	2.730	81.45	10.420		39.20	27.440	19.460	3.728			4.1112	51.390 73.000
		10.250	.250	51.793	27.48		2.684	82.52	10.250		55.10	38.560	19.150	3.698			5.1112	72.000 73.000
		10.192	.279	57.809	27.11		2.669	81.58	10.192		61.60	43.120	19.060	3.689			5.1112	72.000 73.000
		10.136	.307	63.555	26.74		2.653	80.69	10.070		67.80	47.460	18.970	3.680			5.1112	72.000 73.000
		10.020	.365	75.580	26.13		2.622	78.855	11.910		160.70	29.900	18.500	3.674			3393	42.441 62.180
		9.750	.500	102.101	25.31		2.553	73.710	17.060		223.60	41.600	18.110	3.618			5051	63.140 92.600
		9.750	.750	80.101	29.09		2.422	67.200	19.560		296.20	55.100	12.570	9.565			7139	6914 124.00
		9.750	1.000	104.781	26.05		2.291	60.30	30.630		367.00	68.430	12.010	3.465			9.541	11936 134.00
		9.625	1.0625	110.924	25.69		2.258	58.43	32.510		384.00	71.500	11.880	3.447			10.714	13.392 134.00
11	11.75	11.000	.375	45.557	41.17	3.076	2.880	95.030	13.400		217.00	36.930	16.190	4.028			5191	3949 83.10
		10.750	.500	60.076	39.32		2.814	90.760	17.670		280.10	47.680	15.850	3.981			4253	39.91 107.30
		10.750	1.000	114.811	32.36		2.553	74.460	33.110		492.10	83.760	14.370	3.817			8911	10.440 188.90
		12.090	.330	49.773	49.73		3.166	114.80	14.880		328.50	55.900	19.300	4.393			4468	3.1.45 89.59
		12.000	.375	49.562	40.95		3.142	113.097	14.580		319.50	54.370	19.160	4.377			2361	3676 98.59
		11.750	.500	65.418	46.94	3.338	3.076	108.434	19.740		427.50	72.760	18.790	4.335			3925	6102 127.60
		11.500	.625	80.935	44.95		3.011	103.940	24.810		528.70	90.010	18.450	4.293			2903	6.117 134.50
		11.000	.875	96.103	41.13		2.880	95.030	34.750		740.60	126.100	17.710	4.210			6943	8.1.50 134.50
		10.750	1.000	125.491	39.32		2.814	90.760	36.900		441.70	100.700	17.380	4.169			9843	9804 126.90
		10.375	1.1875	150.095	36.17		2.700	84.500	44.160		942.40	116.500	16.820	4.100			9659	1.1948 262.00
		13.375	.375	49.481	60.81		3.504	140.500	13.44		349.90	44.980	23.930	4.891			2235	2.190 101.20
		13.250	.375	49.087	59.71		3.469	137.880	13.31		346.50	44.550	23.720	4.869			2679	3.1.45 101.20
		13.125	.4375	57.269	58.53		3.436	135.300	15.440		429.10	61.290	23.020	4.798			3123	3906 137.90
14	14.00	13.000	.500	72.091	57.45	3.665	3.403	132.730	2.170		483.60	69.110	22.810	4.776			3571	4463 155.50
		12.750	.625	89.779	55.27		3.338	127.680	26.260		598.50	85.500	22.210	4.714			4.1112	5580 189.20
		12.6875	.6563	93.634	54.92		3.323	126.490	27.560		627.50	89.640	22.090	4.700			4.1112	5580 197.20
		12.125	.9375	130.719	49.99		3.174	115.500	38.470		820.50	117.210	21.330	4.630			6.1112	8370 263.70
		11.9375	.9688	134.375	81.635	43.50	3.124	111.960	39.760		847.60	121.080	21.110	4.594			6.1112	8370 263.70
		15.375	.375	56.521	80.78		4.025	185.620	15.40		474.00	59.750	30.750	5.547			2.1112	2441 139.50
		15.250	.375	56.129	79.67		3.992	182.650	15.29		470.60	59.300	30.540	5.527			2.1112	2441 139.50
		15.000	.500	74.271	76.49		3.927	176.700	24.35		731.90	90.060	30.060	5.483			3.1112	3906 205.90
16	16.00	14.939	.5312	81.771	75.83	4.189	3.911	175.700	25.82		774.80	96.852	30.010	5.477			3.1112	4150 217.90
		14.750	.625	97.138	73.13		3.859	168.030	33.20		994.50	124.40	29.370	5.419			4.1112	5291 277.50
		14.500	.750	117.114	71.48		3.796	165.130	35.93		1047.00	130.90	29.140	5.398			4.1112	5540 290.80
		13.937	1.0312	164.868	66.05		3.649	152.600	48.49		1366.00	170.75	28.170	5.309			4.1112	8086 424.10
		13.000	1.500	232.793	57.44		3.403	132.700	68.53		1816.00	227.000	26.380	5.134			5.1112	11720 615.00
		17.375	.375	63.562	102.40		4.547	237.000	17.40		607.00	75.900	39.120	6.255			2.1112	3.1.45 178.90
		17.250	.375	70.585	101.20		4.516	233.700	20.76		906.20	89.63	38.850	6.233			2083	3603 201.70
		17.000	.500	93.445	98.25		4.451	226.980	27.48		1053.00	117.00	38.310	6.190			2778	3473 268.30
18	18.00	16.812	.5938	110.379	96.29	4.712	4.401	222.000	32.41		1238.00	137.00	37.970	6.157			3239	4.1112 308.30
		16.500	.750	139.178	92.55		4.320	213.830	40.81		1560.00	173.30	37.210	6.098			4.1112	5209 378.70
		16.375	.8125	149.146	91.16		4.287	210.600	43.87		1646.00	182.96	37.060	6.085			4.1112	5642 406.70
		15.687	1.1563	208.002	83.67		4.101	193.30	61.18		2182.00	242.33	36.470	5.969			6479	8099 545.50
		14.624	1.6875	293.996	72.72		3.829	168.00	86.46		2934.00	323.32	35.590	5.798			9373	11720 772.10
		19.250	.375	78.599	126.00		5.038	291.000	19.24		744.00	93.000	48.160	6.902			1875	2340 350.50
20	20.00	18.815	.5625	116.777	121.10		4.941	279.80	34.35		1424.00	162.40	47.270	6.875			2812	3515 362.50
		18.750	.625	129.330	119.50		4.909	276.12	38.04		1576.00	178.70	46.970	6.854			3125	3906 402.10
		18.500	.875	178.715	113.20	5.236	4.718	261.89	52.51		2163.00	246.90	45.820	6.769			4335	5418 562.10
		18.187	1.0625	215.806	103.40		4.587	254.80	63.61		2611.00	298.40	45.020	6.710			5234	6542 675.90
		17.731	1.2813	254.146	103.40		4.642	246.90	76.34		3130.00	357.10	44.030	6.634			6276	7845 746.30
		16.312	1.8437	357.524	90.46		4.271	209.00	105.20		4469.00	446.80	42.670	6.458			8957	11523 1010.0
		23.250	.375	94.569	183.80		6.087	424.60	37.83		1822.00	161.90	69.790	8.354			1563	1954 364.2
		23.125	.4375	110.097	181.80		6.051	420.00	43.98		2120.00	187.40	69.450	8.332			1823	2280 424.6
		22.750	.625	156.173	172.10		5.956	406.69	62.49		2975.00	261.70	68.350	8.267			2604	3255 588.2
24	24.00	22.500	.750	164.335	172.10	6.283	5.892	397.61	74.83		3705.00	308.80	67.640	8.224			3125	3906 694.8
		22.375	.8125	178.000	166.40		5.192	394.45	81.03		3852.00	321.00	66.640	8.161			3906	4883 840.8
		21.937	1.0312	223.163	163.23		5.743	377.80	102.96		4881.00	406.80	66.120	8.130			4297	5371 977.5
		21.000	1.500	360.455	149.90		5.498	346.36	106.90		5064.00	546.15	63.590	7.973			6250	7813 1264
		19.625	1.8125	509.622	130.30		5.138	302.00	149.50		7010.00	750.83	60.110	7.750			9.1112	8204 1393 1699.0
26	26.00	25.125	.4375	119.442	214.60		6.578	495.80	35.15		1891.00	210.80	81.700	9.039			1685	1515 2104 496.0
		25.000	.5000	136.172	212.40	6.807	6.545	490.90	40.06		2150.00	239.50	81.300	9.017			1923	1731 2404 566.2
		24.625	.6875	185.859	206.20		6.447	476.30	54.67		2931.00	337.10	80.150	8.953			2644	2380 3305 778.2
28	28.00	27.125	.4375	128.787	250.10		7.101	577.90	37.88		2459.00	257.00	94.990	9.746			1563	1407 1954 570.3
		27.000	.5000	146.852	247.80	7.330	7.068	572.60	43.20		2805.00	291.80	94.600	9.724			1786	1607 2232 656.5
		26.750	.6250	182.624	240.20		6.997	562.00	54.72		3552.00	369.00	93.790	9.680			2679	2410 3349 956.5
		26.500	.7500	218.396	232.50		6.937	551.60	66.24		4302.00	446.70	93.000	9.640			3214	2893 4018 1276
30	30.00	29.000	.5000	157.431	285.40	7.854	7.569	660.50	52.02		3617.00	331.80	108.40	10.410			1875	1688 2344 845.5
		28.875	.5625	176.903	283.30		7.560	654.90	58.52		4067.00	372.80	108.20	10.400			2.1112	1875 2604 951.0
		28.500	.7500	234.396	276.10		7.461	637.90	78.02		5419.00	497.10	107.00	10.340			2890	2.1112 3472 1268
32	32.00	31.000	.5000	167.999	326.10		8.116	754.80	55.72		4.1112	379.00	124.00	11.140			1500	1250 1875 684.0
		30.750	.6250	222.000	321.50	8.377	8.050	742.70	61.60		5.1112	469.00	123.40	11.100			1758	1465 2197 801.0
		30.250	.8750	303.00	311.10		7.919	718.70	85.58		6.1112	655.00	121.40	11.010			2461	2051 3076 1121
34	34.00	33.750	.4750	179.00	364.90	8.901	8.538	894.60	59.53		5.1112	537.50	139.40	11.800			1674	1395 2093 763.0
		33.500	.6250	235.00	358.00		8.377	881.50	78.40		6.1112	705.00	137.30	11.700			2232	1860 2790 1017
36	36.00	35.750	.5000	190.00	410.50	9.425	9.097	948.60	69.46		6.1112	608.50	156.90	12.510			1563	1173 1954 712.0
		35.000	1.000	392.00	393.00		8.901	907.90	110.00		9290.0	930.33	153.50	12.380			2500	1875 2111.0

FORMULAE:

P = Ultimate bursting pressure lbs. per sq. in.
f = Fibre stress in pounds per sq. in.
A = Area of metal in sq. ins.
I = Moment of inertia of pipe section.
Z = Section modulus.
R = Radius of gyration.
Q = Strength factor, representing the strength of the pipe to resist bending action, and is the resisting moment in thousands of foot pounds, the stress in the material being 27000 pounds per square inch. For any other allowable stress in the material the resisting moment is directly proportional.
y = Distance of farthest fibre from axis.
D_1 = External diameter of pipe.
D_2 = Internal diameter of pipe.
t = Thickness of pipe walls.

THEN:

$I = 0.0491(D_1^4 - D_2^4)$ $\quad P = 2f\frac{t}{D_1}$

$Z = 0.0982\left(\frac{D_1^4 - D_2^4}{D_1}\right)$ $\quad R = \frac{1}{4}\sqrt{D_1^2 + D_2^2}$

$Q = \frac{\text{FOOT POUNDS}}{1000} = \frac{I}{y} \times \frac{27000}{1000} \times \frac{1}{12} = \frac{9}{2}\frac{I}{D_1}$

Pipe Wall Thickness

Minimum thickness of pipe wall of different pressures and for temperatures not exceeding 750 F for steel or wrought iron pipe; 406 F for brass and copper pipe; and 450 F for cast iron may be determined with Formula "I" of the A.S.M.E. Pressure piping code, in which

$t_m = (PD/2S) + C$ or $P = (2S/D)(t - C)$

where

t_m = Minimum pipe wall thickness in inches.
P = Internal pressure lbs. per sq. in. gauge. (plus water hammer allowance in case of cast iron pipe conveying liquids

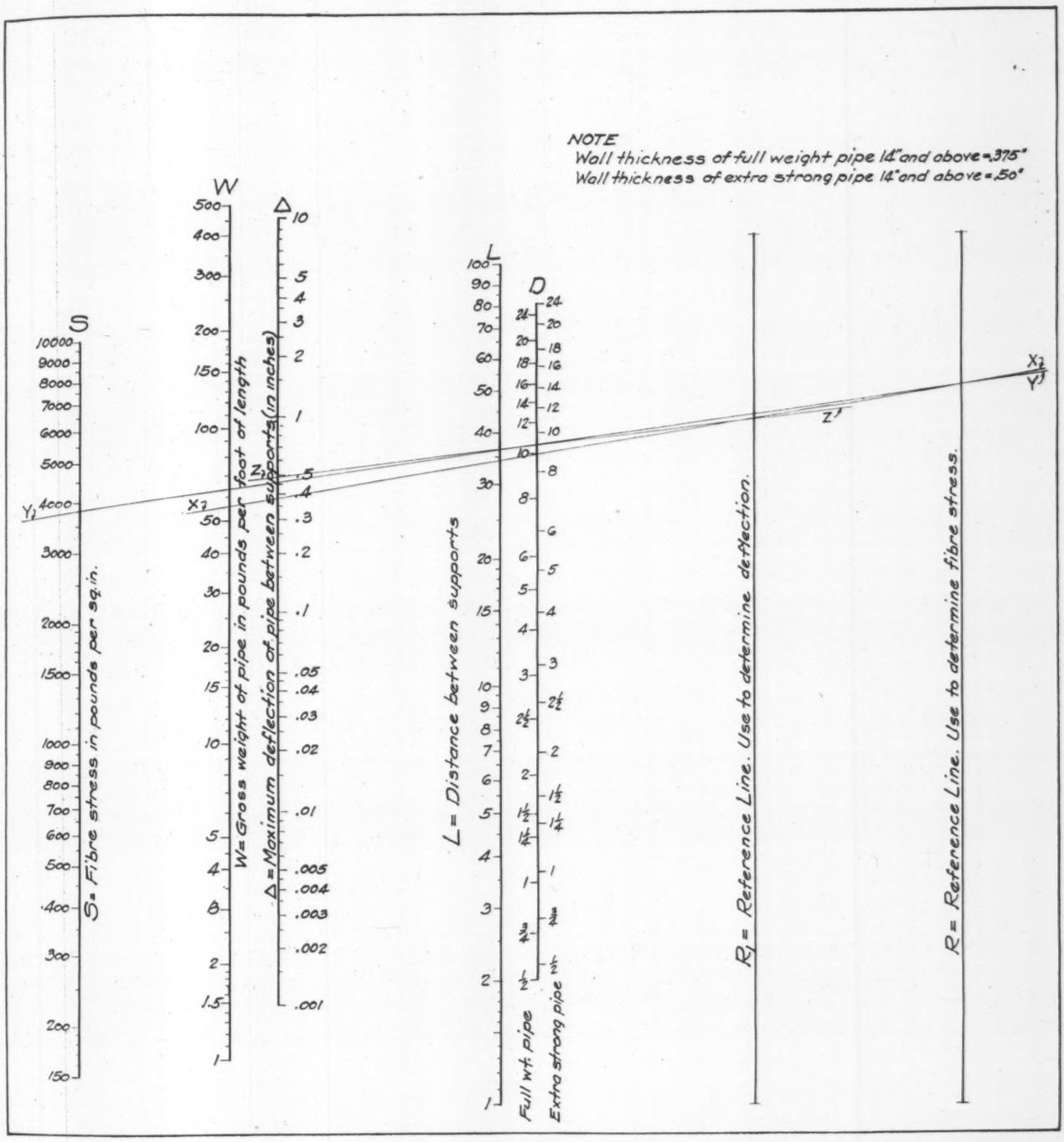

NOTE
Wall thickness of full weight pipe 14" and above = .375"
Wall thickness of extra strong pipe 14" and above = .50"
S = Fibre stress in pounds per sq. in.
W = Gross weight of pipe in pounds per foot of length
Δ = Maximum deflection of pipe between supports (in inches)
L = Distance between supports
Full wt. pipe
Extra strong pipe
R = Reference Line. Use to determine deflection.
R = Reference Line. Use to determine fibre stress.

Fig. 4—Deflection of pipe between supports

$$S = Pd / 2t$$

where

S = Fibre stress in lb per sq in.
P = Internal pressure in lb per sq in. gage.
t = Thickness of pipe wall in inches.
d = Outside diameter of pipe in inches.

Example Shows Use of Charts

An explanation of the use of the charts is given by the following example:

Assume a 10 in. full weight grade A steel pipe line transporting steam at 150 lb per sq in. gage pressure, and having a total temperature of 500 F. From the curve in Fig. 6, it will be seen that grade A pipe at 500 F may be stressed to 14,000 lb per sq in. Since it is necessary to allow for expansion strains, and for corrosion, the permissible stress allowed for dead load deflection in this case, and stress due to internal pressure is 6000 lb per sq in. (This is conservative. Except for extremely long lines it is good practice to use a fairly generous margin of safety). Referring to Table 2 it is found that a 10 in. full weight steel pipe weighs 40.48 lb per ft. The weight of insulation for 10 in. pipe having a temperature of 500 F is 15 lb per ft. This value is shown in Table 3, which gives the weight of 85 per cent magnesia insulation for all sizes of pipe and temperatures up to 600 F.

Summarizing the values known in the problem:

D = Diameter of pipe = 10 in. full weight steel
W = Gross weight of pipe per ft = 40.48 + 15 = Approx. 56 lb

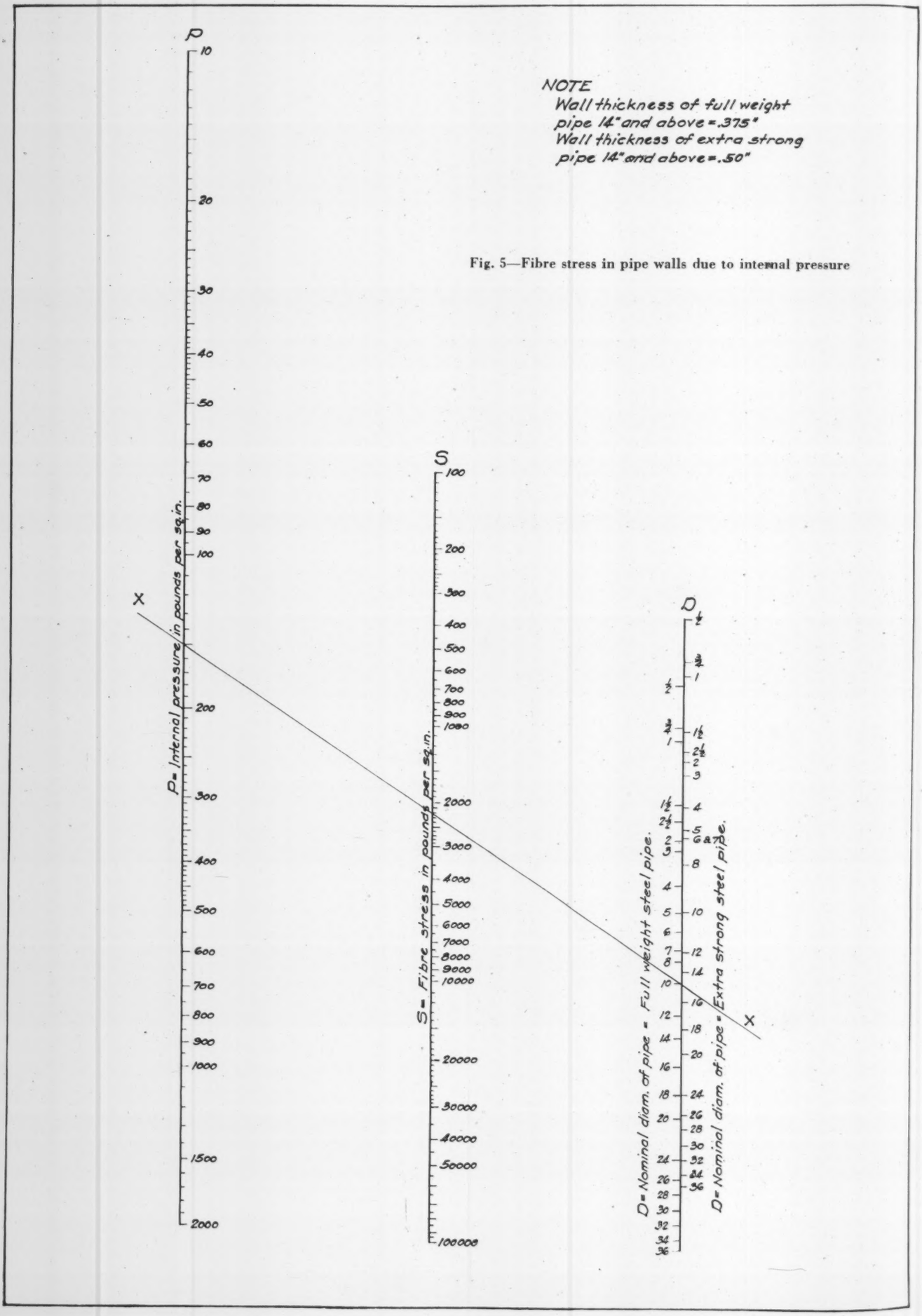

NOTE
Wall thickness of full weight pipe 14" and above = .375"
Wall thickness of extra strong pipe 14" and above = .50"
P
P = Internal pressure in pounds per sq.in.
S
S = Fibre stress in pounds per sq.in.
D
D = Nominal diam. of pipe = Full weight steel pipe.
D = Nominal diam. of pipe = Extra strong steel pipe.
X
X

Fig. 5—Fibre stress in pipe walls due to internal pressure

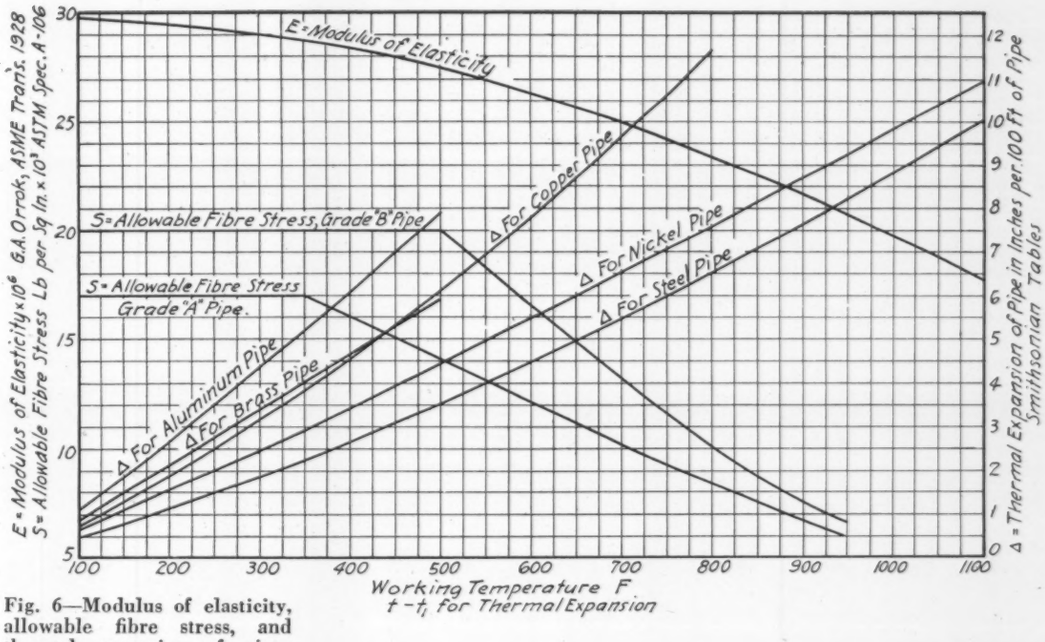

E = Modulus of Elasticity x 10⁶ G.A. Orrok, ASME Trans. 1928
S = Allowable Fibre Stress Lb per Sq In. x 10³ ASTM Spec. A-106
E = Modulus of Elasticity
S = Allowable Fibre Stress, Grade "B" Pipe
S = Allowable Fibre Stress Grade "A" Pipe.
Δ For Copper Pipe
Δ For Nickel Pipe
Δ For Steel Pipe
Δ For Aluminum Pipe
Δ For Brass Pipe
Working Temperature F
t - t₁ for Thermal Expansion
Δ = Thermal Expansion of Pipe in Inches per 100 Ft of Pipe
Smithsonian Tables

Fig. 6—Modulus of elasticity, allowable fibre stress, and thermal expansion of pipes

P = Internal pressure, lb per sq in. gage, = 150
S = 6000 lb per sq in. (allowed for bending and bursting).

Determine the following:

a—Fibre stress in pipe walls due to dead load deflection and internal pressure.

b—The deflection of pipe between supports.

c—The distance between supports.

First calculate the stress due to internal pressure. Refer to Fig. 5. Draw a line X-X intersecting P line at 150 lb per sq in., and D line at 10 in. full weight steel pipe. Read on S line at the intersection of X-X line, the fibre stress in lb per sq in. due to internal pressure, which in this case is 2200 lb per sq in. From the example it is noted that the total permissible stress due to internal pressure and dead load deflection is 6000 lb per sq in. Subtracting the stress value due to internal pressure just determined, it is found that the allowable stress due to dead load deflection is 6000 — 2200 = 3800 lb per sq in.

Now, refer to Fig. 4. Draw a line X-X intersecting W line at 56 lb per ft, and the D line at 10 in. full weight steel pipe. Project this line to reference line R. Draw a line Y-Y intersecting reference line R at intersection point of X-X line, and intersecting S line at 3800 lb per sq in. Read on the L line the distance between supports, which in this case is 36 ft 6 in. Draw a line Z-Z intersecting the reference line R_1 at the point of intersection of the X-X line, and intersecting the L line at the point of intersection of the Y-Y line. Project this line to the Δ line and read the maximum deflection of the pipe between supports, which in this case is 0.49 in.

For very exacting conditions where it is necessary to calculate each problem Table 2 has been constructed; from it, physical values of commercial pipe sizes are combined for easy reference.

Fig. 6 is reprinted from the April, 1935, HEATING, PIPING AND AIR CONDITIONING[1] and shows the permissible stress and modulus of elasticity at working temperatures, as well as the thermal expansion of different pipe materials at working temperatures.

[1] "Design of Modern Industrial Piping Systems—Flexibility of Piping," by F. L. Snyder, HEATING, PIPING AND AIR CONDITIONING, April, 1935, pp. 181-186.

Table 3—Weight per Foot of Pipe Insulation

Nominal Pipe Diam.	Weight of Insulation Corresponding to Specified Thickness at Working Temp.				
	212 F to 266 F	267 F to 337 F	338 F to 387 F	388 F to 499 F	500 F to 600 F
½"	.72	.72	.72	1.56	2.52
¾"	.84	.84	.84	1.68	2.76
1"	.96	.96	.96	1.92	3.00
1¼"	1.10	1.10	1.10	2.04	3.24
1½"	1.20	1.20	1.20	2.28	3.36
2"	1.56	1.56	2.52	3.84	3.96
2½"	1.80	1.80	2.88	4.20	4.33
3"	2.04	2.04	3.24	4.80	4.93
3½"	2.28	2.28	3.60	5.16	5.40
4"	2.76	2.76	3.96	5.64	6.60
5"	3.24	4.56	6.60	7.68	11.20
6"	3.84	5.28	7.44	8.64	12.48
8"	5.28	6.60	9.23	12.00	15.00
10"	6.50	7.92	11.10	14.30	15.00
12"	9.23	9.23	12.70	20.30	20.30
14"	11.30	11.30	15.00	22.50	22.50
16"	12.60	12.60	16.80	25.10	25.10
18"	13.90	13.90	17.30	27.70	27.70
20"	15.20	15.20	20.30	30.40	30.40
24"	17.90	17.90	23.80	35.70	35.70

The weights are per foot of finished insulation on the pipe, and are based on accepted specified thicknesses. They do not include weather-proof covering.

Air Conditioning Installations

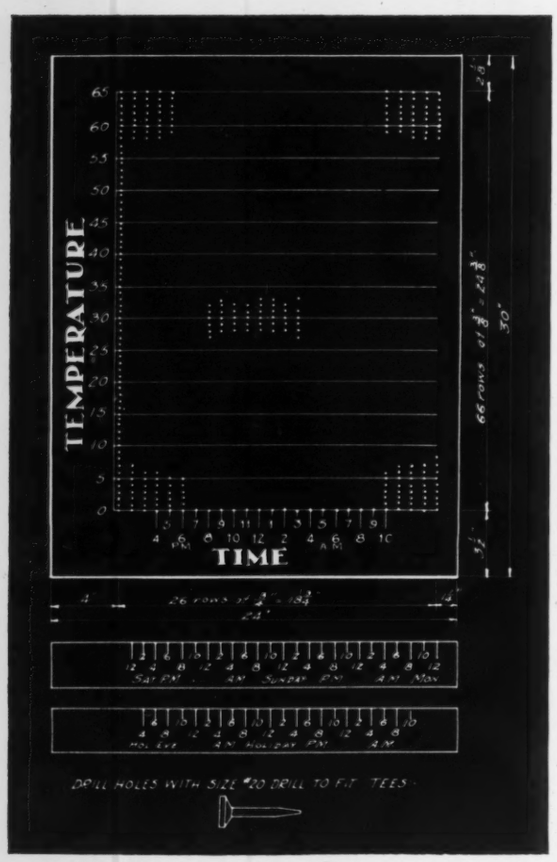
The following data on number of air conditioning installations and connected horsepower for the first eleven months of last year compared with the twelve months of 1934 supplement the air conditioning review published in the January, 1936, H. P. & A. C., pp. 1-2:—

Territory	Jan. 1-Nov. 30 1935 (11 Months) No.	Hp	1934 (12 Months) No.	Hp	Total Dec. 1, 1935, Including Prior to 1934, 1934, and 11 Months of 1935 No.	Hp
ARKANSAS						
Pine Bluff	23	251.5	8	13	31	264.5
CONNECTICUT						
Hartford	14	172	5	507	28	1002.5
MASSACHUSETTS						
Boston	56	1603.5	44	2735	139	9040.5
OHIO						
Dayton	20	149.5	38	269.25	87	1601.75
RHODE ISLAND						
Providence ...	8	99	10	105	21	834

Outdoor Temperature Graph Aids in Heating Building for Morning Occupancy

By **Joseph W. Degen***

THE "manual and erasable" graph illustrated was developed at the Equitable building, New York City, to show graphically the trend of the street temperature. Since office occupancy starts at 9 a. m. it is necessary that the building be adequately warmed by that time. This requires early morning heating to start at a time dependent on outdoor temperature, the time heat is off and extent and the time the temperature has been below 65 F.



Time — temperature graph in use, above, and, below, diagram of layout

As an aid to the engineers in determining when to turn on steam, several recording and indicating thermometers and a steam meter previously were provided. The recording thermometer shows the street temperature on a 10 in. circular chart, which is checked by a remote bulb indicating thermometer. In addition, a 30 point remote station electrical indicating thermometer gives the street temperature as well as the temperatures at some twelve "key" rooms in the building; these latter readings are taken at stated times and entered on a log by the engineer on watch.

However, it was found that despite the attention required of the engineers through the actual writing of the readings on the log, the work sometimes became routine to such an extent that, once or twice a season, a sudden drop in temperature or a continuous abnormally low temperature was not appreciated sufficiently and soon enough to permit adequate heating by the 9 a. m. deadline. Apparently what happened was that, as the last reading was noted, a mental comparison was made only with the previous reading so that the continuous drop of a degree or two per hour did not assume much significance. The continuity and extent of the change, even though shown on the circular chart, was difficult to see and appreciate until almost a full revolution of the chart had taken place.

The graph shown here was developed to overcome the difficulty, and it supplements use of the instruments. As the hourly readings are taken, a peg is inserted in the hole corresponding to the time and temperature; this gives a definite "living" record which is started new each afternoon at 4 p. m. and continued to 10 a. m. the next day.

The chart is laid out to permit the insertion of extra legends on the time ordinate for the periods from Saturday noon to Monday morning and from 4 p. m. on the day before a holiday to the morning of the day after the holiday. These cards are seen hanging from the lower right hand corner of the graph.

When designing the original layout it was thought that a cord from peg to peg would be necessary properly to delineate the curve; this cord, on a re-winding reel, is seen in the lower left-hand corner. It has not been used, since it was found that the use of large headed golf tees for pegs gives sufficient continuity to the curve.

The results from the use of the graph have been quite satisfactory. The engineers accepted the gadget enthusiastically with the claim that they can now not only see the trend of temperature but can see it from a distance due to the size of the board. They also get a good mental image of the temperature record each time a peg is inserted.

*Supervising Engineer, Equitable Office Building Corp., New York, N. Y.

Heating · Piping
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American Society of Heating and Ventilating Engineers JOURNAL SECTION

FEBRUARY 1936

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Corrosion Studies in Steam Heating Systems

By R. R. Seeber,[1] *(MEMBER)*, F. A. Rohrman,[2] and G. E. Smedberg[3] *(NON-MEMBERS)*

Houghton, Mich.

This paper is the result of research sponsored by the American Society of Heating and Ventilating Engineers in co-operation with the Michigan College of Mining and Technology

THIS paper is the second of a series presenting information obtained in the investigation of corrosion in steam heating systems.[4]

Up to the present time 40 corrosion tests have been conducted at various pressures and with various gas concentrations. In them the following points were considered:

1. The effect of pressure on the corrosion rate.
2. The effect of oxygen and carbon-dioxide on the corrosion rate.
3. Correlation of the rate of corrosion, as measured by the corrosion tester, to the actual life of pipe.
4. An electric resistance method of determining corrosion rates.

The results of these tests are offered now in order to make the information available to those interested and thereby to promote discussion. However, many additional tests are necessary before the role that each factor plays in the corrosion problem is fully understood.

The authors wish to stress the effect of change in certain operating conditions upon the rate of corrosion and to call attention to a method of determining rates of corrosion which seems to offer the possibility of greatly reducing the time required for such tests.

Description of Apparatus Used

The corrosion testing apparatus is essentially a closed and wet-return type of heating system which is similar in construction to the ordinary steam house-heating system, consisting of steel piping and cast iron radiators. It uses a 66-gal boiler for generating the necessary steam. In the boiler are inserted four immersion-type heaters with a total capacity of 9 kw. The pressure of the system is kept constant by proper controls. From the boiler, steam flows through four corrosion loops in which the elements for the determination of the rate of corrosion are placed. At the bottom of each corrosion loop, valves are located to draw off the samples of condensate for analysis of oxygen and carbon-dioxide content and for pH values. A 40 sq ft radiator is in the line midway between the second and third corrosion loops. The condensate and the steam from the last loop flow into a 16-gal receiver and thence to the boiler. To cut down infiltration of the atmospheric gases, all valves above the water line of the system are packless and all joints are tight. A Beach-Russ vacuum pump is used to maintain a vacuum when desired.

Distilled water is added to the boiler by means of a connection on the top of the boiler; city water is added through the feeder line.

The temperatures at the boiler and at the top and bottom of each loop are recorded by thermometers in suitable wells. The temperatures of the bottom part of loops 3 and 4 are measured by recording thermometers. The pressures in the boiler, at the top of each loop, and in the receiver are indicated by mercury gages.

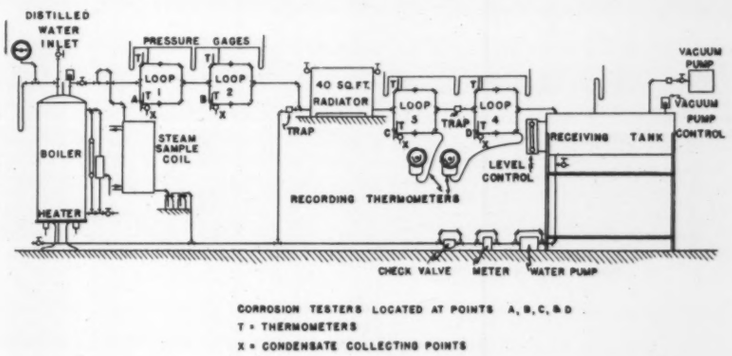


Fig. 1—Line diagram of corrosion test apparatus

When a sample of the steam is being taken for analysis, it is necessary to entrain in the condensate all of the gases accompanying the steam. This is done by the use of a water-cooled condensation coil (Fig. 4).

Methods of Withdrawing Condensate Samples

One of the most difficult procedures encountered is that of withdrawing from the apparatus a sample of condensate accurately representative of the conditions inside the system. In the course of the first eleven tests four different methods were tried before satisfactory ones were found. They were:

1. Nitrogen method (Fig. 5).
2. Bottle-train method (Fig. 6).
3. Mercury-bottle method (Fig. 7).
4. Water-syphon method (Fig. 7).

[1]Professor of Mechanical Engineering.
[2]Assistant Professor of Chemistry.
[3]Research Mechanical Engineer.
[4]See Corrosion Studies in Steam Heating Systems, A. S. H. V. E. TRANSACTIONS, Vol. 40, 1934.

Presented at the 42nd Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Chicago, Ill., January, 1936.

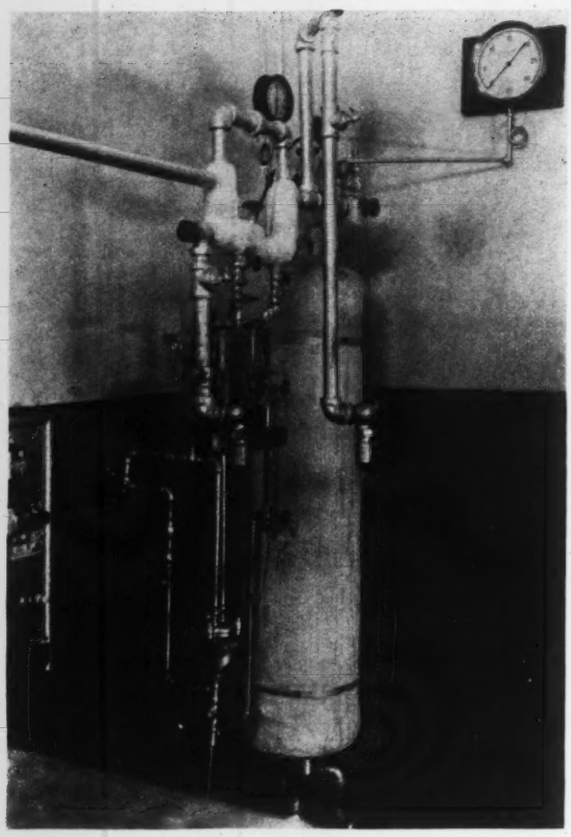


Fig. 2—View of boiler

In the first method a stream of nitrogen was used to expel the air from a vertical pipe section attached to the loop. The condensate was then collected in this vertical section and forced out into the collecting bottles by means of a stream of nitrogen. This method, though preventing the pollution of the condensate by the air, gave a lower concentration of oxygen and carbon-dioxide because of the high partial pressure of the nitrogen, and was therefore discarded.

In the second method the condensate was permitted to flow through a train composed of two bottles which were connected in series below the loop. With this method it was possible for the air originally in the bottles to contaminate the sample of condensate. To overcome this objection a third method was devised which proved successful and is being used. In it the air in the bottles is expelled by means of mercury, and as the mercury is withdrawn the condensate flows in to replace it. Apparently this method gives a sample of condensate which is as representative of actual conditions as can be obtained. The fourth method consisted of the use of the same bottles as in the third method, with a vacuum produced inside the train by the use of a water syphon. After a vacuum was obtained inside the train, the valve from the loop was turned on and the train filled with condensate. This fourth method, like the third, appeared to be entirely acceptable and is being used in the work.

Washed asbestos, glass wool, and cotton filters are used in filtering the condensate sample as it is withdrawn from the loop. Cotton filters seem to operate with the least difficulty.

Description of Tester and Method of Cleaning

The corrosion tester used in this work is of the type devised by the *National District Heating Association* (Fig. 8). It consists of a standard ¾-in. pipe plug, into which is threaded a brass retaining frame. The corrosion specimen consists of three helical coils mounted in the frame and insulated from one another and from the supporting frame by micarta couplings. The terminal micarta couplings are threaded into the frame and the pipe plug.

The coils are made of Bessemer steel wire 0.05 in. in diameter; the steel had been taken from a heavily cropped ingot (below the upper one-third), and pickled and annealed. The coils are approximately 11/32 in. in outside diameter and 1 in. in length, and weigh approximately 3 grams. Except for the coils, all metal surfaces exposed to the corrosive action are protected by Sarva paint.

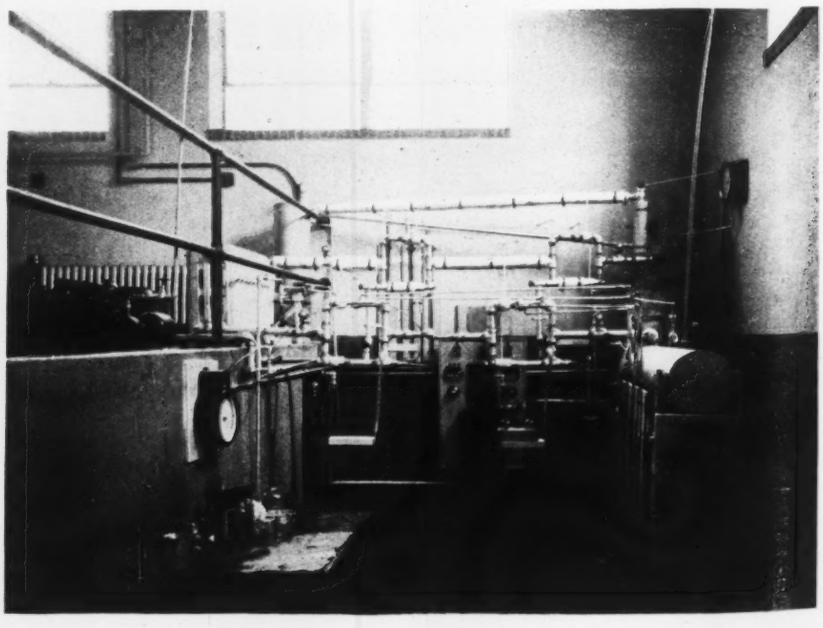


Fig. 3—View of apparatus

The accompanying table shows the analysis of the wire used in making the coils.[5]

Phosphorus	0.10 per cent
Sulphur	0.07 per cent — 0.08 per cent
Manganese	0.04 per cent — 0.10 per cent
Carbon	0.08 per cent — 0.10 per cent

During the progress of the work many methods were tried to clean the wire samples before use. Two methods have been particularly successful. The first, suggested by the *National District Heating Association*, is given:

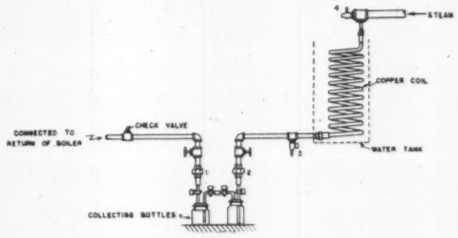


Fig. 4—Steam sample coil and collecting bottles

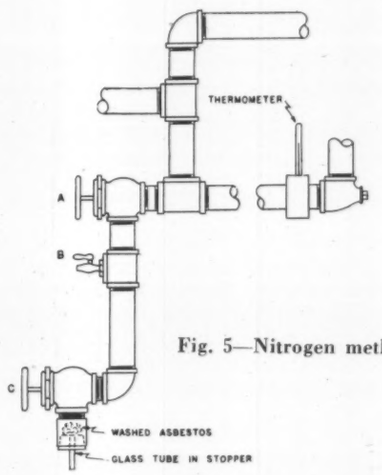


Fig. 5—Nitrogen method

The coils are placed in a flask, containing ether or carbon tetrachloride and equipped with a reflux condenser, and are boiled for approximately 30 min. The coils are then removed from the solvent and dried at a constant temperature of 107 F for two hours.

The second method consists of immersing the coils in a solution of dilute sulphuric acid and drying them with benzol or acetone.

Of several methods of cleaning the samples after use, it was found that the most satisfactory is to boil the coils in a solution of sodium hydroxide and zinc and dry them with pure benzol. Other methods which were tried included the following:

1. Cleaning the coils by passing an electric current through a slightly acid solution, the wire samples being used as the cathode.
2. Immersing the coils in a 0.33 per cent solution of sulphuric acid for a short period of time.
3. Immersing the coils in a 15 per cent solution of sulphuric acid with 5 per cent of the inhibitor. (Super-In-Control.)

[5]Analysis by American Steel and Wire Co.

Method of Procedure in Test

At the beginning of each test a new set of wire coils are cleaned, weighed, and placed upon the insulating frames. Water is added to the boiler, together with the amount of chemicals needed to produce the required type of steam, and the apparatus is started. After the steam has been tested and found to be as desired, the corrosion testers are placed in their respective loops and new charts are placed in the recording thermometers. The system is then operated for approximately 200 hours.

The first condensate samples are withdrawn for analysis the day after the test is started, and the second and final samples the day before the test is completed. Usually, also, both the condensate and the steam are analyzed the day the test is ended.

The gages are read each time an analysis is made. After the test has been conducted for the required length of time, the apparatus is shut down and the corrosion coils are removed from the loops, cleaned of their products of corrosion, dried, and weighed. From the loss in weight the corrosion rate in inches penetration per year is calculated by the following formula:

$$R = \frac{A}{B \times C}$$

where:

R = corrosion rate as average penetration in inches per year.
A = loss of weight in pounds per square inch.
B = weight of metal in pounds per cubic inch = (0.2782 lb.)
C = duration of the test in years.

Method of Analysis

The reagents and the methods of analysis used in this work are those recommended by the *National District Heating Association*, with certain additions and variations.

The samples, after being withdrawn from the test set-

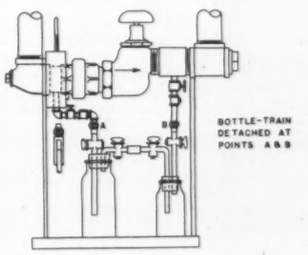


Fig. 6—Bottle-train method

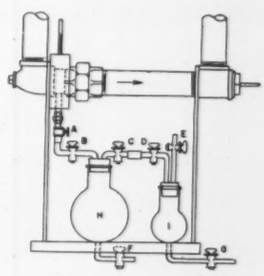


Fig. 7—Mercury-bottle method

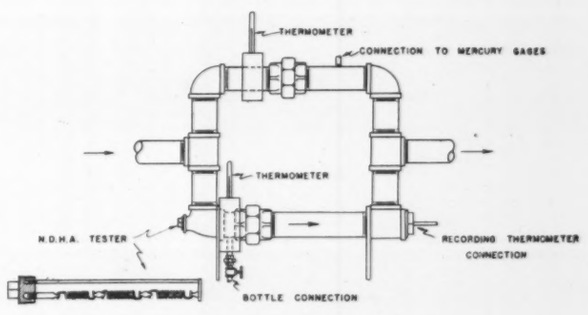


Fig. 8—Corrosion test loop

up, are placed in a cooling vat and cooled to 20 C; they are then analyzed for oxygen, carbon-dioxide, and pH value.

The Winkler method of oxygen analysis is used throughout.

Three methods of carbon dioxide analysis were tried, two of which were discarded. The first method consisted of adding to 100 cc of the condensate sample 25 cc of barium hydroxide, and titrating with HCl to the phenolphthalein end-point. This method of analysis, it

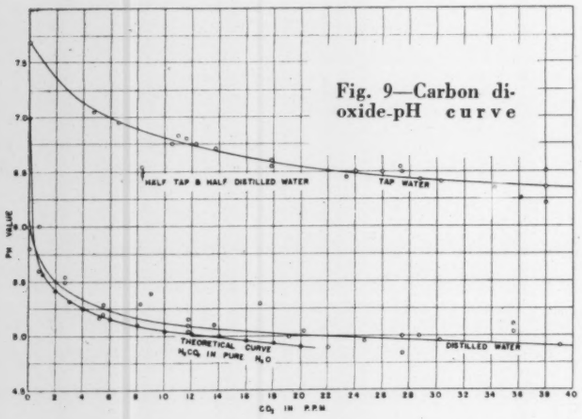


Fig. 9—Carbon dioxide-pH curve

was found, introduces the possibility of considerable error unless enough barium chloride is added to reduce greatly the solubility of barium carbonate. Further, in it the time element presents a difficulty: if the amount of HCl necessary to titrate the solution is added and a period of 5 to 10 min is allowed to elapse before more HCl is added, the results obtained by this method do not check those obtained by the other methods.

The second method was by direct titration with sodium carbonate.

The third method was by direct titration with barium hydroxide (Dr. Guernsey) to the phenolphthalein end-point. ($Ba(HCO_3)_2$). This method was found to be much more rapid and accurate, and is being used.

During the greatest number of tests the pH value of the condensate was measured by a quinhydrone set, where accuracy was determined by checking it against that of another of the same type, against a comparator, and against standard buffer solution. Later tests have made use of a glass electrode for measurement of the pH value.

Carbon Dioxide—pH Relationship

To test the quinhydrone set-up and to study the effect of carbon dioxide on the pH value, a series of tests was conducted by saturating different solutions of distilled and tap water with carbon dioxide and measuring the pH value. (Fig. 9 shows a curve for pH as related to carbon-dioxide content for tap water and for distilled water and also shows the theoretical curve of the relationship.) The close comparison of the actual with the theoretical values appears to confirm the accuracy of the method of analysis.

Time Required for Tests

In order to determine the correct length of time for each test, the time taken for the first eleven tests was varied from one to four weeks. A period of about 200 hours was found to be the most desirable.

Pressure vs. Corrosion Rate

The effect of pressure upon the corrosion rate was studied during the first eleven tests by using the same quality of steam but varying the pressure from 20 in. Hg vacuum to 2 lb per square inch gage.

Discussion of Results

The corrosion rates in loops 1 and 2 on the supply side of the radiator were practically zero for every condition of operation. This result was expected, as it is found in practice that supply lines are not much corroded. Since this is the case, the discussion concerns itself with only the loops 3 and 4 on the return side of the system and may be divided as follows:

1. Relation of pressure to corrosion rate.
2. Relation of rate of condensation to corrosion rate.
3. Relation of temperature to corrosion rate.
4. Correlation tests.
5. Electric resistance method of determining corrosion rates.

1. In the tests the steam qualities were kept as nearly constant as possible, while the system operated at various pressures ranging from 20 in. Hg vacuum to 2 lb per square inch gage. Previous to these tests the system was made as tight as possible by several applications of

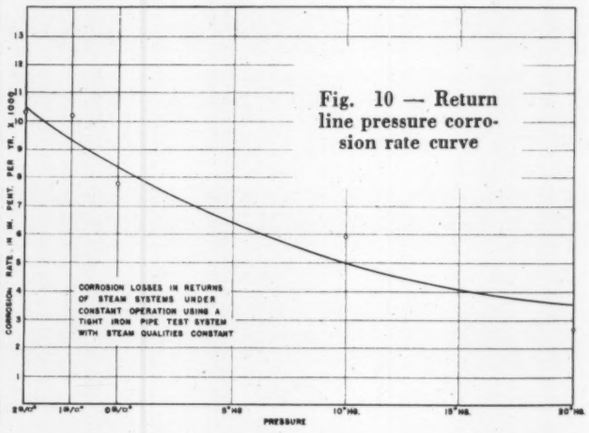

CORROSION LOSSES IN RETURNS OF STEAM SYSTEMS UNDER CONSTANT OPERATION USING A TIGHT IRON PIPE TEST SYSTEM WITH STEAM QUALITIES CONSTANT
PRESSURE

Fig. 10 — Return line pressure corrosion rate curve

shellac to all the joints of the system while under vacuum. Table 1 gives the data of the first eleven tests used as the basis for the curve shown in Fig. 10. This curve gives the relationship of the corrosion rate in loop No. 3 to the operating pressure, several factors influencing this relationship. At the higher pressures the gases are forced to stay in solution and the rate of flow of condensate is greater, both conditions acting to increase the corrosion rate. Under vacuum operation the gases tend to be drawn from the solution and the rate of flow is lower.

2. The rate of flow of condensate has an important bearing on the corrosion rate. Fig. 11 shows the rate of condensation in the various loops of the system under different pressure conditions. It is difficult to compare the corrosion rate as obtained from this apparatus with that in a large commercial installation, because of the small rate of flow of condensate. The higher velocity

Table 1—Data as Basis for Curve 10, with Steam Qualities Constant

Test No.	Loop No.	Gage Pressure lb/sq in.	Average Temp. F	Average pH	Corrosion Rate in. pent./yr x 1000			
					A	B	C	Ave.
1	3	2 lb	109	8.3	9.63	12.41	9.13	10.39
1	4	2 lb	93	8.0	10.29	10.82	10.32	10.48
2	3	2 lb	109	7.4	10.13	11.36	8.97	10.15
2	4	2 lb	94	7.0	10.55	7.28	10.50	9.44
3	3	20 in. Hg	110	8.2	1.20	0.475	1.82	1.20
3	4	20 in. Hg	110	8.2	6.19	8.62	7.11	7.30
4	3	20 in. Hg	101	8.0	6.17	2.94	3.08	4.06
4	4	20 in. Hg	93	7.7	13.02	11.16	9.00	11.07
5	3	0 lb	101	7.3	11.93	14.00	15.00	13.64
5	4	0 lb	88	7.1	6.31	5.72	7.60	6.54
6	3	0 lb	157	8.3	1.13	0.75	0.89	0.92
6	4	0 lb	140	7.7	3.67	2.57	3.53	3.25
7	3	0 lb	83	6.02	8.34	9.54	7.71	8.53
7	4	0 lb	82	5 9	8.39	6.24	4.99	6.52
8	3	1 lb	87	5.8	10.44	10.43	7.69	9.52
8	4	1 lb	83	5.8	7.30	8.52	5.70	7.17
9	3	1 lb	115	5.9	12.06	9.57	10.80	10.81
9	4	1 lb	101	5.8	14.24	9.72	10.79	11.58
10	3	10 in. Hg	120	6.9	6.10	7.32	6.37	6.77
10	4	10 in. Hg	115	6.7	9.07	7.75	6.98	8.27
11	3	10 in. Hg	137	7.0	5.40	4.56	4.06	5.00
11	4	10 in. Hg	134	7.0	7.57	5.29	5.39	6.08

tends to wash off both the protective coatings which form and also the products of corrosion which protect the metal to some extent. There is a possibility of some erosive action in cases of high velocity.

3. The temperature of the corroding medium is an important factor, as brought out by Speller and others. A series of tests was conducted with various temperatures in loop 3. Figs. 12 and 13 show how the corrosion rate varied with the temperature. In loop 3 the corrosion rate increased with the temperature up to a certain point and then dropped as the temperature increased. This action is due to the fact that the increase in temperature drives the gases from the solution into the gaseous phase above.

The curve in Fig. 13, taken from Speller's *Corrosion Causes and Prevention,*[6] shows the effect of temperature in both an open and a closed system. The presence or absence of a gaseous phase above the corroding solution has a marked effect on the rate of corrosion as related to temperature. In the arrangement used in this work a gaseous phase was present in the top of each loop; consequently the gases were able to escape and thus to cause a drop in the corrosion rate.

4. To relate the rate of corrosion as measured by the *National District Heating Association* Tester, which is given in inches of penetration per year, with the actual life of pipe, these tests were conducted as follows:

In the college heating system a pipe loop was inserted in a return line. In this loop was mounted a standard corrosion tester and a section of black iron pipe in which had been milled three spots 0.003 in. thick. Fig. 14 shows the construction.

The wire coils were weighed and placed on the retaining frame, which was then installed in the loop. Water was passed through the tester until one of the thin sections broke through, the test coils being removed and their corrosion rate determined. From the corrosion rate and the time in breaking through the thin section the correlation was made.

Each individual test requires about six months to complete, and several tests are necessary to arrive at an accurate average of the relationship. The tests so far have been made at atmospheric pressure, the inside of the thin section being turned to a smooth surface and the thin sections milled.

The average penetration rate of these three tests roughly checks that indicated by the *National District Heating Association* testing wires, the figures being 100 units penetration by break-through to 84 units shown by the tester.

[6]1st edition, 1926.

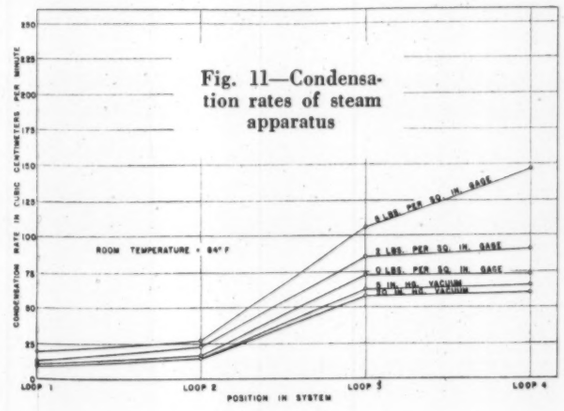


Fig. 11—Condensation rates of steam apparatus

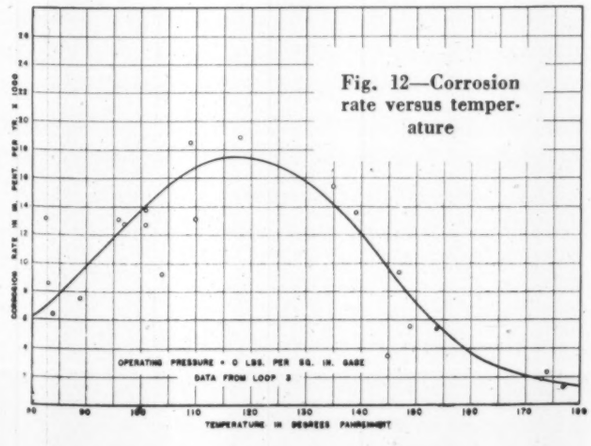


Fig. 12—Corrosion rate versus temperature

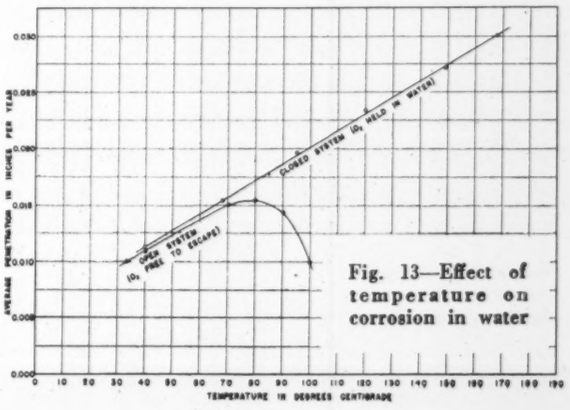

CLOSED SYSTEM (O2 HELD IN WATER)
OPEN SYSTEM (O2 FREE TO ESCAPE)
AVERAGE PENETRATION IN INCHES PER YEAR
TEMPERATURE IN DEGREES CENTIGRADE

Fig. 13—Effect of temperature on corrosion in water

5. The use of the increase of the resistance of a specimen to determine its corrosion penetration is not new. Early use of this method was made by E. Wilson.[7] Later, J. C. Hudson[8] made tests with the method to determine its accuracy, and used it extensively in his study of atmospheric corrosion.

The following discussion deals with the application of the resistance method of corrosion measurement in a tight iron pipe steam system. The method is based upon the proved principle that the resistance of a uniform conductor varies inversely as the area of its cross-section. The fact that the products of corrosion have such a high resistance as compared with the resistance of the conductor itself makes it possible to measure the true resistance of the metal itself without first cleaning it. This has a distinct advantage over the gravitational method, which requires that the specimen be thoroughly cleaned without removing the metal itself.

In order to measure successfully the amount of corrosion by the change of the resistance of a specimen it is necessary to overcome several obstacles:

1. Contact resistance.
2. Type of specimen and holder.
3. Temperature effects.

Contact Resistance. When low resistances are being measured, the effect of the contact resistance can best be eliminated by the use of the Double Kelvin bridge circuit. This circuit (Fig. 14) makes it possible to accurately measure the true resistance between the potential leads with only a negligible error due to the contact resistance.

The bridge is operated by first adjusting the branch resistors so that $\frac{R_a}{R_b} = \frac{R_c}{R_d}$. The standard resistance, R, is then adjusted until the galvanometer shows no deflection upon closing the key. In this state of balance the current flowing through the unknown resistance, X, is necessarily the same as that flowing through R. The relation between the standard resistance and the unknown resistance is then determined by the four branch resistors—*i.e.*,

$$\frac{R}{X} = \frac{R_b}{R_a} = \frac{R_d}{R_c}$$

Type of Specimen and Holder. The ideal specimen to use for this system must have necessary strength, proper steel composition, uniformity, and large exposed area as compared with volume. Further, it must cause a minimum of errors due to pitting and it must secure proper connection of potential leads without introducing a different kind of metal. It was found that a thin ribbon of steel would fulfill these requirements most fully, as shown in the following discussion.

If a conductor of circular cross-section is used, the diameter must be reduced in order to increase the ratio between the exposed area and the volume. This seriously reduces its strength and allows large pitting errors. However, by reducing its thickness a conductor of rectangular cross-section can be given a larger ratio of exposed area to volume without loss of the necessary strength. This shape also helps to eliminate the error due to pitting since a pit affects only a much smaller portion of the cross section. Furthermore, potential leads can be formed by splitting the ends of the specimen. Thus both leads can be brought out of the corrosive medium before any artificial joints are made.

The preparation of the specimen is important because of the necessity of a proper steel composition and of uniformity of cross section. Rings about ¾ in. in width are cut from a standard 2 in. iron pipe and split open. These are hot rolled into strips approximately 18 in. long by ¾ in. wide by 0.015 in. thick. The strips are then ground down as thin as is practical. By careful machining the specimen is made as uniform as possible, a point of importance when the resistance changes are being reduced to penetration units. Finally, the finished strips are thoroughly annealed without oxidizing.

The specimen holder is so designed that the resistance readings can be taken without disturbing the system or

[7] E. Wilson, *Proc. Physical Soc.*, 1926, 39, 15.
[8] J. C. Hudson, *Proc. Physical Society*, 1928, 40, 107.
J. C. Hudson, *Trans. Faraday Soc.*, 1929, 25, 48.

[9] A detailed description of the Kelvin Bridge can be found in Notes on the Kelvin Bridge, Note Book No. 4, by the Leeds and Northrup Co.

Table 2—Corrosion Test Data with Steam Qualities Constant

Test No.	Loop No.	Gage Pressure lb/sq in.	Average Temp. F	Average pH	Corrosion Rate in. pent./yr x 1000			
					A	B	C	Ave.
1	3	2 lb	109	8.3	9.63	12.41	9.13	10.39
1	4	2 lb	93	8.0	10.29	10.82	10.32	10.48
2	3	2 lb	109	7.4	10.13	11.36	8.97	10.15
2	4	2 lb	94	7.0	10.55	7.28	10.50	9.44
3	3	20 in. Hg	110	8.2	1.20	0.475	1.82	1.20
3	4	20 in. Hg	110	8.2	6.19	8.62	7.11	7.30
4	3	20 in. Hg	101	8.0	6.17	2.94	3.08	4.06
4	4	20 in. Hg	93	7.7	13.02	11.16	9.00	11.07
5	3	0 lb	101	7.3	11.93	14.00	15.00	13.64
5	4	0 lb	88	7.1	6.31	5.72	7.60	6.54
6	3	0 lb	157	8.3	1.13	0.75	0.89	0.92
6	4	0 lb	140	7.7	3.67	2.57	3.53	3.25
7	3	0 lb	83	6.02	8.34	9.54	7.71	8.53
7	4	0 lb	82	5.9	8.39	6.24	4.99	6.52
8	3	1 lb	87	5.8	10.44	10.43	7.69	9.52
8	4	1 lb	83	5.8	7.30	8.52	5.70	7.17
9	3	1 lb	115	5.9	12.06	9.57	10.80	10.81
9	4	1 lb	101	5.8	14.24	9.72	10.79	11.58
10	3	10 in. Hg	120	6.9	6.10	7.32	6.37	6.77
10	4	10 in. Hg	115	6.7	9.07	7.75	6.98	8.27
11	3	10 in. Hg	137	7.0	5.40	4.56	4.06	5.00
11	4	10 in. Hg	134	7.0	7.57	5.29	5.39	6.08

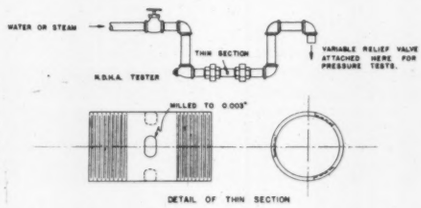


Fig. 14—Correlation tester

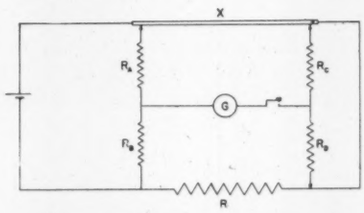


Fig. 15—Double Kelvin bridge

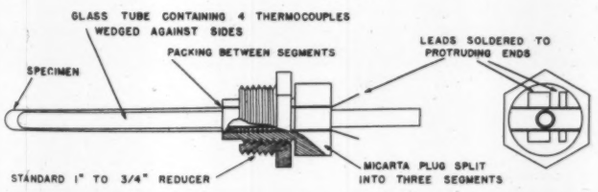
removing the specimen. The current and potential leads are taken out through a split micarta plug. The drawings in Fig. 16 show clearly the method of bringing out the leads and the arrangements made for inserting insulated thermocouples.

Temperature Effects. With the use of an iron conductor and the Kelvin Bridge, temperature has two effects: the first is to change the resistance of the specimen as the temperature changes; and the second is to set up an unbalanced thermocouple emf when the two iron and copper junctions of the potential leads are at different temperatures. The latter effect is easily eliminated by placing the two junctions in an ice-filled vacuum bottle so that they will remain at a constant and equal temperature.

The resistance of the iron specimen used does not increase directly as the temperature rises, but begins to increase more rapidly at the higher temperatures. One way to correct for temperature changes is to take the temperature of the specimen at the time of the resistance reading and multiply this resistance as read by the proper correction factor as taken from a prepared table. This necessitates the use of an expensive potentiometer to get temperature readings correct to the nearest tenth of a degree Fahrenheit. Several additional chances for error also enter the measurements, not to mention the extra work entailed. A more effective method is described.

On the same sheet with the resistance vs temperature curve is also plotted the emf vs temperature curve of a copper and constantan thermocouple. See Fig. 17, which shows that for the range of temperatures plotted the specimen resistance and thermocouple voltage bear a constant relationship to each other. The fact that these curves follow each other so closely is utilized in this method. As shown in the circuit diagram, Fig. 18A, the thermocouple is combined directly with the bridge circuit by being placed in series with the galvanometer. The sensitive junction of the thermocouple is placed in the corrosive solution near the specimen, but is highly insulated from the solution and specimen. The arrangement and method of insulating are shown in Fig. 16.

Fig. 16—*Above*, specimen. *Below*, holder


GLASS TUBE CONTAINING 4 THERMOCOUPLES WEDGED AGAINST SIDES
PACKING BETWEEN SEGMENTS
LEADS SOLDERED TO PROTRUDING ENDS
SPECIMEN
STANDARD 1" TO 3/4" REDUCER
MICARTA PLUG SPLIT INTO THREE SEGMENTS

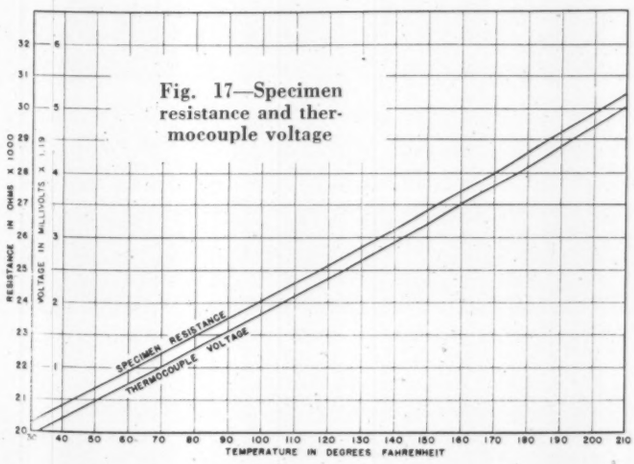


Fig. 17—Specimen resistance and thermocouple voltage

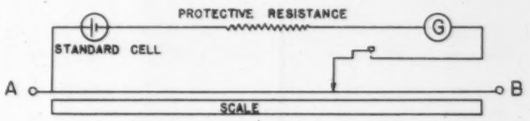


Fig. 18B—Current adjustment

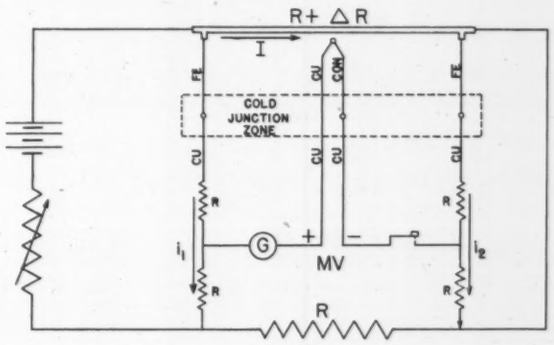


Fig. 18A—Diagram of thermocouple connection

Using the letters on the diagram, Fig. 18A, the mathematical solution is:

Let

I = Current through specimen in milliamperes.

r = Resistance of each branch of the bridge.

R = Resistance of specimen at the temperature of cold junction zone.

$\triangle R$ = Increase in resistance of specimen because of temperature increase above that of cold junction zone.

MV = emf furnished by thermocouple in millivolts.

Assume that the circuit is balanced with the standard resistance at R, that the temperature of the specimen is above that of the cold junction zone, and that no current is flowing through the galvanometer. The equations can be obtained from this circuit,

$$(1)\quad I(R+\triangle R)+i_1 r-MV-i_2 r=0$$
$$(2)\quad IR+i_2 r+MV-i_1 r=0.$$

By subtracting (2) from (1) the equation is obtained,

$$I\triangle R=2\,MV.$$

It is now apparent that by proper control of the current through the specimen, the resistance as read will have been automatically corrected to the resistance at the temperature of the cold junction zone. It is also apparent that as the cold-junction resistance of the specimen changes, the current adjustment also must be changed in order to bring about the proper temperature corrections. The accuracy with which the current must be adjusted depends on the temperature difference between the cold junction and the specimen. If this is about 100 F and the proper current is about 3 amperes, the current must be adjusted correctly to the third decimal (3.000) in order to assure a temperature correction to the nearest tenth of a degree.

The current is adjusted with the necessary accuracy as shown in Fig. 18B. The current in passing through the manganin slide wire, *AB*, produces a voltage drop which is balanced against the standard cell. Since the electromotive force of the standard cell and the resistance of the slide wire are constant at room temperatures, the scale can be calibrated in amperes. However, since the current adjustment is dependent upon the resistance of the specimen, it is most convenient to mark the scale directly in ohms corresponding to the cold junction resistance of the specimen.

Conclusion

A schematic diagram of the complete circuit is shown in Fig. 19. Four thermocouples are used in series, an arrangement which gives a more sensitive adjustment and a better average temperature correction. The galvanometer and key are connected to the blades of a D. P. D. T. switch, so that they can be conveniently used for either current or resistance adjustments. All resistors are made of manganin in order to avoid corrections due to temperature changes. Special note was made of all contacts and connections in order to reduce current variations to a minimum.

With this circuit it becomes comparatively simple to take a corrected resistance reading. Since the current scale is calibrated in ohms, it is only necessary to alternately adjust the current and standard resistance until both scales give the same same reading. The current adjustment is made by turning the galvanometer switch to the position marked *I*, moving the slide *A* to the approximate resistance of the specimen, and varying the current rheostats until the galvanometer does not deflect. The resistance adjustment is now made by turning the galvanometer to the position marked *R* and adjusting the slide *B* until the galvanometer does not deflect.

With the selection of this type of specimen the calculation of the penetration from the resistance changes is comparatively simple. Since the resistance of a uniform conductor is inversely proportional to the area of its cross section, the assumption can be made that the resistance is also inversely proportional to the thickness of the specimen. This assumption will introduce only a negligible error, for any change in width will be only a very small percent of the total width.

$$R_1 t_1 = R_2 t_2$$

Where

R_1 = original resistance.
R_2 = final resistance.
t_1 = original thickness.
t_2 = final thickness.
$t_2 = R_1 t_1 / R_2$.

The penetration is then equal to half of the total change of thickness since the specimen is corroding from two sides.

$$P = t_1 - t_2/2.$$

It is obvious that this penetration calculation can be only as accurate as the original thickness measurements. With a good micrometer the average thickness can be estimated only to the second place. The average thickness can be measured more accurately by weighing the specimen and calculating tthe thickness from the length, width, and specific gravity of the strip.

Table 3—Corrosion Test Data

Test No.	Loop No.	Gage Press.	Ave. O_2 cc/1	Ave. CO_2 PPM	Ave. Temp. F	Ave. pH	Corrosion Rate in. pent/yr x 1000			
							A	B	C	Ave.
12	3	0	1.9	41	84	5.9	7.83	5.72	5.32	6.29
12	4	0	2.02	48	79	5.1	5.57	4.59	7.91	6.02
13	3	0	1.17	35	89.3	5.8	7.89	6.84	7.67	7.47
13	4	0	0.993	36	81.7	5.8	5.13	4.96	4.04	4.71
14	3	0	0.45	25	144.9	6.3	4.39	2.57	0	2.32
14	4	0	0.612	25	124.3	5.4	5.17	1.95	5.11	4.08
15	3	0	1.22	56	85	5.8	13.339	13.358	12.470	13.06
15	4	0	1.35	58	86	5.8	5.479	5.23	6.469	5.73
16	3	0	0.98	30	104	5.8	9.018	8.414	9.616	9.02
16	4	0	1.02	31	87	5.8	4.606	5.689	4.792	5.09
17	3	0	0.374	31	139	5.8	11.373	12.714	16.566	13.55
17	4	0	0.582	48	113	5.5	0.9818	0.674	0.800	0.82
18	3	0	1.08	30	108.5	5.7	17.08	17.62	20.59	18.43
18	4	0	1.27	33	93	5.7	3.56	6.54	3.90	4.67
19	3	0	0.91	24	134.4	5.9	15.14	17.31	13.21	15.32
19	4	0	1.17	28	105.5	5.9	8.04	5.15	5.45*	6.21
20	3	0	.....	.....	138	.....	0.977	2.088	1.041*	1.37
20	4	0	.....	.....	109	.....	2.313	1.165	1.017*	1.50
21	3	0	1.23	35	97	5.6	13.27	10.88	13.77	12.64
21	4	0	1.08	35	88	5.5	8.62	10.21	9.77	9.53
22	3	0	1.3	38	118	5.4	20.42	18.26	17.72	18.80
22	4	0	1.21	40	98	5.4	12.36	12.34	13.28	12.67
23	3	0	1.87	35	101	5.6	11.86	11.6	14.37	12.61
23	4	0	1.32	31	88	5.5	7.86	11.2	11.6	10.22
24	3	0	1.25	6	110	5.7	13.074	13.22	12.75	13.01
24	4	0	1.39	13	96	5.8	9.03	9.25	10.44	9.57
25	3	0	1.83	10	96	5.9	17.24	12.28	9.64	13.05
25	4	0	1.45	10	87	5.9	7.77	11.85	8.78	9.47
26	3	0	0.766	0.5	149	5.6	4.678	5.684	6.068	5.48
26	4	0	0.715	6	121	5.6	6.087	6.557	5.909	6.18
27	3	0	1.41	0.6	147	6.0	8.79	9.79	9.42	9.33
27	4	0	1.39	3.0	117	5.2	8.89	8.34	6.95	8.06
28	3	0	1.934	1	174	5.1	2.36	1.85	2.59	2.27
28	4	0	0.744	3.5	153	4.9	7.41	7.98	8.13	7.84
29	3	5lbsqin	1.67	0	183	5.6	1.907	2.015	2.508	2.15
29	4	5lbsqin	1.81	0.65	157	5.5	1.336	2.310	3.05	2.35
30	3	5lbsqin	1.115	0	192	6.2	1.66	1.75	1.66	1.69
30	4	5lbsqin	2.08	0	160	6.1	3.91	3.87	4.09	3.96
31	3	5 in. Hg	0.346	0	171	6.5	1.07	1.02	1.05	1.04
31	4	5 in. Hg	0.485	0	149	6.5	2.19	2.28	2.22	2.23
32	3	5 in. Hg	0.522	0	170	6.2	1.598	1.153	1.422	1.39
32	4	5 in. Hg	0.798	0.68	150	5.8	5.45	5.03	5.51	5.33
33	3	5 in. Hg	0.440	0	172	6.4	1.252	0.747	1.21	1.07
33	4	5 in. Hg	0.962	0	150	6.3	5.36	4.57	5.46	5.13
34	3	5lbsqin	0.58	0	192	6.4	1.39	1.35	2.202	1.65
34	4	5lbsqin	0.76	0	161	6.4	4.91	4.58	5.40	3.96
35	3	0	0.50	0	177.6	6.3	1.017	1.446	1.322	1.26
35	4	0	0.676	0	150	6.4	3.00	2.83	2.90	2.93
36	3	0	0.531	0	177	6.1	1.0666	1.2533	1.3165	1.21
36	4	0	0.597	0	147	5.9	4.3774	5.3676	3.9484	4.56
37	3	5lbsqin	0.55	0.45	190	5.8	0.9756	1.152	1.292	1.14
37	4	5lbsqin	0.61	5.1	156	5.7	4.353	5.624	5.443	5.14
38	3	No Corrosion Samples Analysis Method Tests								
38	4									
39	3	0	0.794	0.56	173	5.8	1.73	1.722	1.9	1.78
39	4	0	0.575	2.44	143	5.8	3.09	3.935	4.28	3.73
40	3	0	0.952	2.18	154	6.3	5.20	5.35	5.39	5.31
40	4	0	0.78	3.62	131	6.3	8.22	9.11	6.77	8.03

*Nitrogen Test.

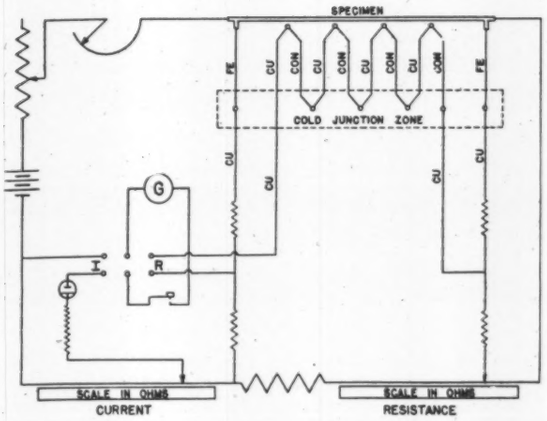


Fig. 19—Complete circuit diagram

The advantage of this method over the gravitational method lies chiefly in two points: (1) measurements can be made without disturbing the set-up, and (2) the increased sensitivity of the method makes it possible to get definite results in a shorter time. These two facts will facilitate the work of obtaining curves of the corrosion rate against time, temperature, and the other variables.

The range of tests conducted is not sufficiently wide as yet for an attempt to be made to correlate the various factors in their combined effect in producing corrosion in return piping. It is felt that the results given bear out the following general statements for type of system tested. Other factors being constant, the corrosion rate will vary directly with the oxygen content of the condensate.

Other factors being constant, the corrosion rate will vary directly with the free CO_2 content of the condensate, at least up to about 30 parts per million. One part per million of oxygen appears to have about the same corrosive effect as between twenty and thirty parts per million of CO_2.

Increase of temperature for the same pressure increases the corrosion rate up to a certain point, from where it decreases rapidly with further increase of temperature. Increased rate of flow of condensate increases corrosive effect.

Decrease of pressure carried in the system, the quality of steam being the same, decreases the corrosion rate in a tight system.

Table 4—Steam Sample Analysis

Test No.	Loop No.	Ave. O_2	Ave. CO_2	Temp. F	pH
26	3	2.37	15	70	5.9
27	3	4.58	0	70	6.4
28	3	3.84	2	70	6.1
29	3	0.315	0	70	5.6
30	3	3.95	0.68	70	6.2
31	3	3.25	0	70	7.1
32	3	2.78	0	70	6.9
33	3	4.48	0	70	6.5
34	3	2.08	0.7	70	6.6
35	3	2.15	0	70	6.8
36	3	1.13	0	70	6.6
37	3	0.98	11.6	70	5.45
39	3	1.47	4.89	70	5.8
40	3	1.52	13.05	70	6.6

Acknowledgment

Acknowledgment is due to A. E. Felt, H. V. Williamson, and F. L. Partlo for assistance in the tests and in the preparation of the report.

The development of the electric resistance method and the actual construction and calibration of the instruments necessary to insure its proper operation were the work of H. V. Williamson.

American Engineering Council Holds Annual Meeting

The 16th Annual Meeting of the *American Engineering Council* was held in Washington, D. C., January 10-11, 1936, at the Mayflower Hotel, and was attended by delegates from the 42 member organizations.

The newly elected officers are Dean A. A. Potter, president; R. E. Flanders, vice-president (two-year term); and J. S. Dodds, vice-president (one-year term). The Executive Committee includes F. J. Chesterman, chairman, Public Affairs Committee; C. O. Bickelhaupt, chairman, Membership Committee; A. J. Hammond, vice-president; C. E. Stephens, treasurer, and William McClellan, chairman, Finance Committee. F. M. Feiker was re-elected executive secretary.

A. S. T. M. Index to Standards

A new index to *A. S. T. M.* Standards and Tentative Standards has been issued by *American Society for Testing Materials*, 260 S. Broad St., Philadelphia, Pa. This publication is of service in ascertaining whether *A. S. T. M.* has issued any standard specifications or test methods covering particular engineering materials or subjects, and is also of help in locating references to publications in which the standards have appeared.

All items are listed in the Index under appropriate key-words according to the particular subjects covered. A list is also given of the specifications and tests in numeric sequence of their serial designations.

Copies of this publication are available upon written request to *A. S. T. M.* headquarters.

Fred R. Low Dies

Fred R. Low, who was well known in the fields of engineering and journalism, died on Wednesday, January 22, 1936, at his home in Passaic, N. J., at the age of 75.

Mr. Low achieved recognition as an engineer and editor. He made several power plant inventions and published 4 technical books in the power field. His journalistic career began when he became associated with the *Journal of Commerce* of Boston. Coming to New York in 1888 Mr. Low became the fifth editor of *Power*, of which he was editor emeritus at the time of his death.

Mr. Low received honors as past president of the *American Society of Mechanical Engineers*, former mayor of Passaic, and honorary member of the *British Institution of Mechanical Engineers*. He also received the honorary degree of Doctor of Engineering from Rensselaer Polytechnic Institute. Mr. Low always maintained an active interest in engineering and he was chairman of two important committees of the *A. S. M. E.* dealing with the codification of safety rules for the construction of steam boilers and unfired pressure vessels and rules for testing boilers, turbines, engines and other power equipment.

Mr. Low was an honorary member of the *National Association of Practical Refrigerating Engineers* and of the National Board of Boiler and Pressure Vessel Inspectors and a member of the *National Association of Power Engineers*, the *Vereines Deutscher Ingenieure*, the *Newcomen Society*, Engineers' Club of New York, and Boston, Yountakah Country Club, Nutley, N. J., and the Plymouth Golf Club, New Hampshire. He also was past president of the Passaic City Club and a member of several masonic orders.

Airfoil Fan Characteristics

By **W. A. Rowe*** ***(MEMBER)***, **Detroit, Mich.**

THE airplane propeller is an efficient device when used for the purpose of producing end thrust for which it is intended. It provides both high acceleration and high velocity in the air stream. These attributes render it less suitable for a ventilating fan, if a highly efficient and quiet fan is to result. In the latter instance it is desirable to move a large volume of air at as low a velocity as possible, with consequent low end thrust.

Another serious fault of the airplane propeller, when used as a fan, is its characteristic swirl at the tips of the blades. A typical example in the case of a small desk or circulating fan is shown in Fig. 1.[1] Fig. 2 represents typical air flow distribution through an airplane propeller. There is a distinct negative flow beyond the tips of the blades with a sharp reversal of the air stream as it returns back through the blades. When the same kind of blade is used in a fan the same condition is obtained. This blade design prevents the most effective part of the blade from doing its share of the work of discharging its quota of air through the orifice (Fig. 3). This factor may be eliminated by a radical change in the design of the blade tips, the orifice, or of both (Fig. 4).

The contraction in the area of the air stream passing through and beyond the orifice ring has the effect of increasing the effluent air velocity. In the case of a fan discharging to the atmosphere, all of the energy represented by the velocity head in the air stream is lost.

*Mechanical Engineer.

[1]Study of the Flow of Air with a Stroboscope, by Harold E. Edgerton, *Mechanical Engineering*, April, 1935. Fig. 1 reproduced by permission.

Presented at the 42nd Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Chicago, Ill., January, 1936.

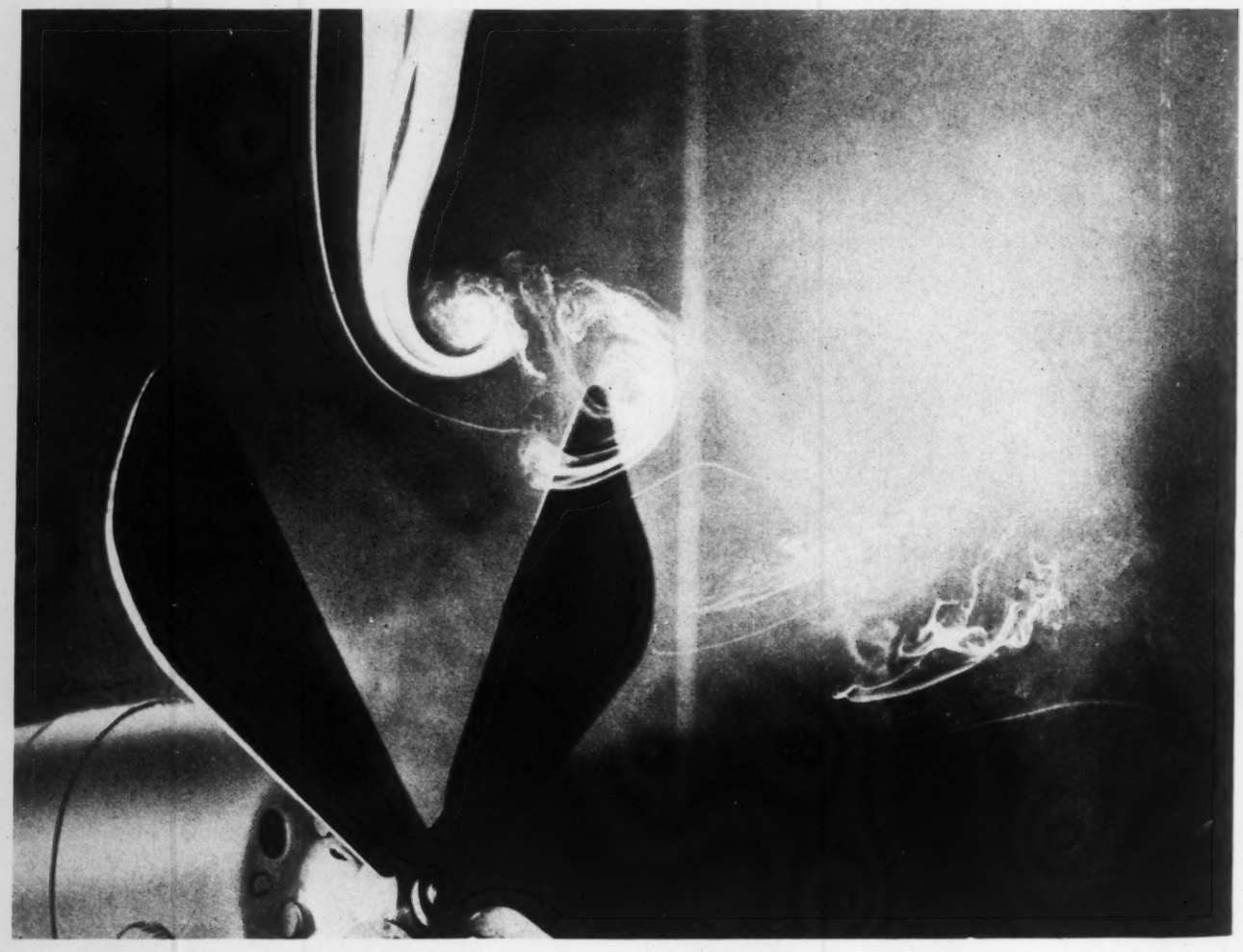


Fig. 1—Flow of air through tip of fan

Anything that can be done to lessen the contraction in the air stream will reduce the velocity pressure loss and increase the fan efficiency.

In the case of the airplane propeller the diameter of the vena contracta will amount to 85 per cent of the blade diameter. In a fan with modified blade tips, sufficient to eliminate the tip swirl, the minimum diameter of the air stream will be nearer 90 per cent, and with the addition of a carefully proportioned streamline orifice may reach a value of 95 per cent, which is approximately the limits to be obtained. The latter value corresponds to about 90 per cent of the area; the remaining 10 per cent represents the dead area at the center of the fan blades, where there is no measurable air velocity.

Attempts have been made to increase the effectiveness of the center third diameter of the blades, where the blade velocity is low, in an effort to improve the fan efficiency. Unfortunately this is the region where the blade angle is already high, and any further increase in its angle of attack only serves to aggravate the disturbance to air flow at the back of the blade. A comparison of the continuity of air flow at low angles of attack as compared to the conditions which occur at larger angles is illustrated in Figs. 5 and 6.

One method of reducing the effluent air velocity is with the use of a discharge duct or collar. If the collar is made of equal diameter to the orifice and not less than one diameter in length, the air stream will expand beyond the point of greatest contraction and fill the duct. This reduces the air velocity and the velocity head, and increases the mechanical efficiency proportionately.

Results of comparative tests of a fan with and without a collar on the discharge is shown in Fig. 7. With the collar there is an increase in the efficiency at the free delivery capacity without the collar, viz. 6000 cfm, of 52 per cent, as compared with the same fan discharging to atmosphere without the collar. With this fan the diameter of the air stream at its point of greatest contraction is 90 per cent of the orifice ring diameter. The area ratio is 81 per cent, the velocity ratio 1.23, and the velocity pressure ratio 1.52. It will be noted that the last value is identical with the increase in the mechanical efficiency.

At other points of operation than at free delivery the increase in the efficiency will be found to be in proportion to total pressure ratios, as indicated in Table 1.

Table 1—Comparative Test Results of Airplane Fan With and Without Collar[a]

Test Without Collar							Test With Collar		
CFM	Vel.	V.P.	S.P.	T.P.	H.P.	M.E.	S.P.	T.P.	M.E.
6000	1407	0.120	0	0.120	0.255	0.445	0.062	0.182	0.675
5000	1170	0.083	0.092	0.175	0.251	0.55	0.135	0.218	0.685
4000	938	0.053	0.167	0.220	0.242	0.575	0.19	0.243	0.633
3000	705	0.030	0.223	0.253	0.23	0.520	0.23	0.26	0.533
When Velocity is Increased 23 per cent and V. P. 52 per cent									
6000	1730	0,180	0	0.180	0.255	0.675			
5000	1440	0,125	0.092	0.217	0.251	0.683			
4000	1155	0,080	0.167	0.247	0.242	0.643			
3000	865	0.045	0.223	0.268	0.23	0.550			

[a] Air Weight = 0.0725 lb per cubic foot. Velocity Constant = 4072.

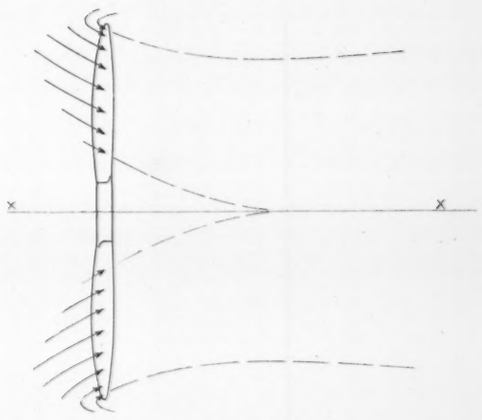


Fig. 2—Air flow distribution through airplane propeller

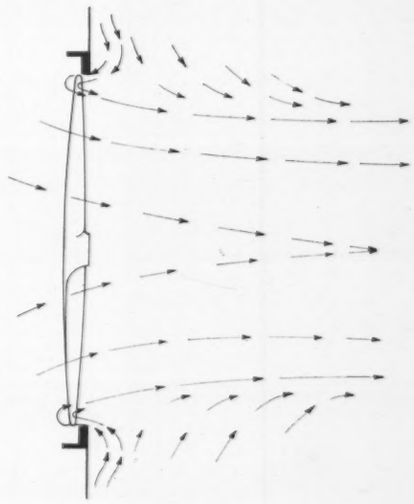


Fig. 3—Air flow through airplane propeller fan with sharp-edge opening

Fig. 4—Air flow through airfoil propeller fan with stream-line orifice

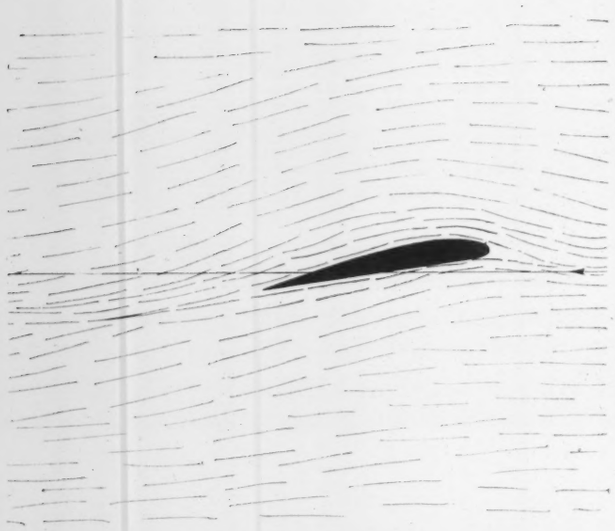


Fig. 5—Fan blade air flow with low angle

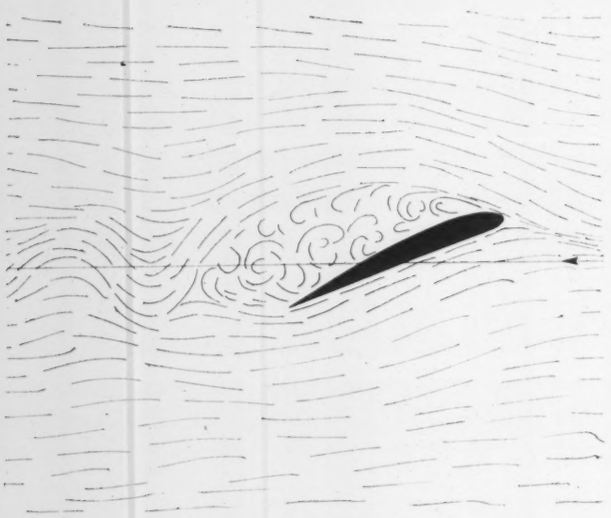


Fig. 6—Fan blade air flow with large angle

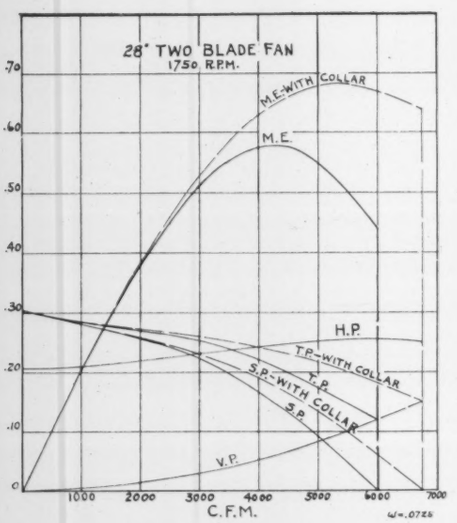


Fig. 7—Airplane fan performance curves with and without discharge collar

The agreement of the results when the fan is credited with the actual air velocity it is producing with the results of the test with the collar indicate excellent recovery of velocity head in the high ratios of volume, and reducing toward no delivery.

If in the previous example a fan had been used giving a higher air stream coefficient, the decrease in velocity would have been less, and the possible improvement in the efficiency would have been less using the collar.

The collar also serves a second function by effectively eliminating the tip swirl of the fan. With the addition of the collar a situation results where the lower the fan efficiency, the greater the possible improvement. The Fan Test Code[2] provides that fan ratings made from tests with collar shall specify *For installation with ducts.* Generally the fan user is not aware of the fact that the ratings are totally unrepresentative of the performance of the fan when wall mounted and discharging to atmosphere. In all such cases ratings for both methods of application should be given.

A two blade airfoil revolving about its own axis is graphically represented in Fig. 8. As the blade revolves any element of an area at any radius r will, relative to the air, move in a helical path on the surface of an imaginary cylinder of the same radius. In one revolution the element will advance from A to B, assuming no slip. This distance is the *Pitch,* and its ratio to the blade diameter is called the *Pitch Ratio.*

If the surface of the cylinder to be developed is assumed, the path of the element will be indicated by the diagonal, and the angle between the long side of the rectangle and the diagonal will be the same as the angle of the blade element referred to the plane of rotation. Then

$$Tan\ b = \frac{Pitch}{2\pi r.} \qquad (1)$$

Referring to Fig. 9 and plotting as abscissa the distance $\frac{Pitch}{2\pi}$ from the axis of the blade, any diagonal to that point from any element of area at any radius r will include an angle with the blade's vertical axis equal to the angle of the blade element with the plane of rotation. With blades of constant pitch the angle of the face of the blade with the plane of rotation continually increases

[2] A.S.H.V.E. Standard Test Code for Disc and Propeller Fans, Centrifugal Fans and Blowers, (A.S.H.V.E. TRANSACTIONS, Vol. 29, 1923).

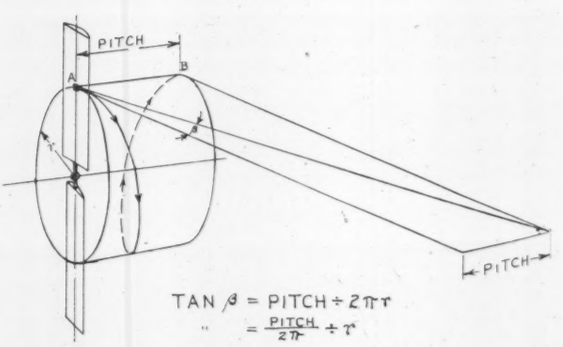


Fig. 8—Diagram of airfoil fan blade revolving about its axis

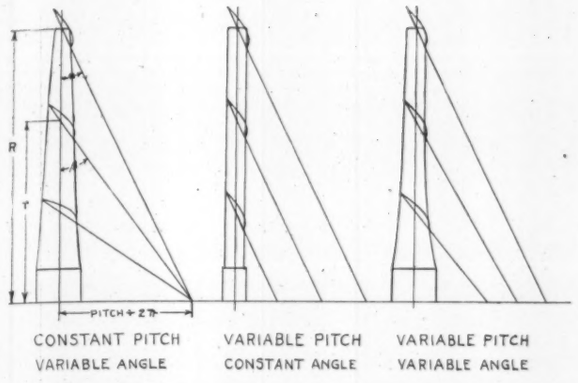


Fig. 9—Airfoil fan blade pitch and angle relationships

as the center is approached. In that case, unless low tip angles are started, blade angles are soon reached, as the center is approached, too great for smooth stream flow at the back of the blade.

Where the blade angle is maintained constant, the pitch will be variable at different radii, being greatest at the tip and decreasing as the center is approached.

There is a third type in which both the blade angle and the pitch are variable, and it is this type which has proven to be suitable for fan purposes.

With any uniformly varying pitch the mean pitch will occur at two-thirds of the radius and can be expressed by the formula:

$$Mean\ Pitch = 2/3\ \pi\ D\ Tan\ b, \qquad (2)$$

where b is the blade angle with the plane of rotation at ⅔ radius. Then

$$Pitch\ Ratio = \frac{2/3\ \pi\ D\ Tan\ b}{D} = 2/3\ \pi\ Tan\ b \qquad (3)$$

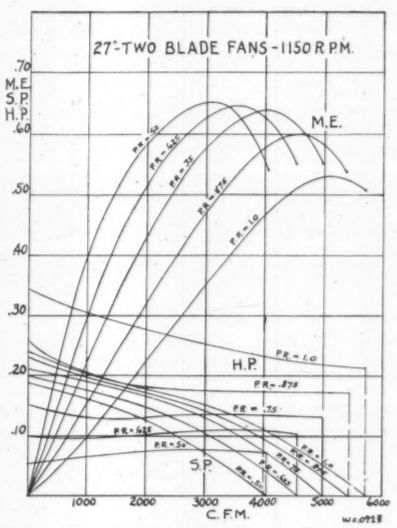


Fig. 10—Performance curves of 27 in. two blade fans, 1150 rpm

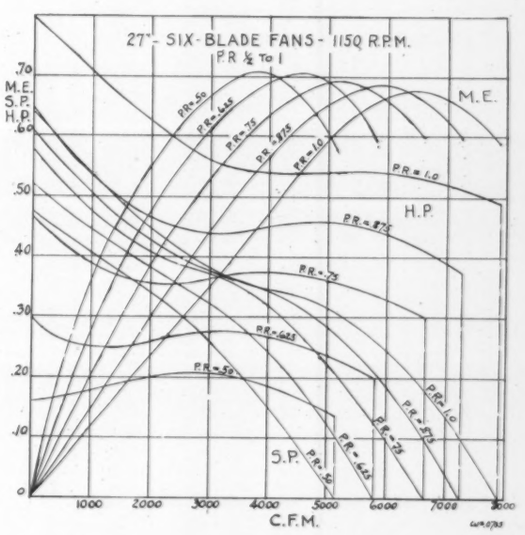


Fig. 12—Performance curves of 27 in. six blade fans, 1150 rpm

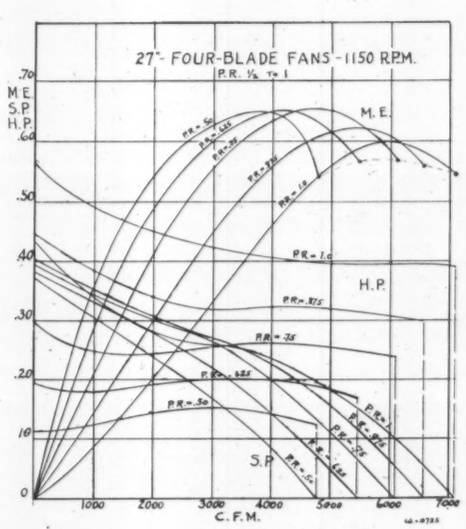


Fig. 11—Performance curves of 27 in. four blade fans, 1150 rpm

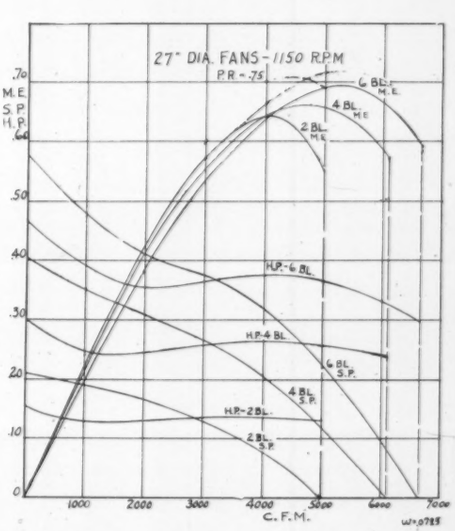


Fig. 13—Comparison curves of two, four and six blade fans, pitch ratio 0.75 and mean blade angle 20 deg.

Development of an efficient fan involves the determination of optimum values or proportions of blade form, and area distribution, thickness ratio and type of airfoil section for different blade angles, and rate of pitch variation. Also an efficient streamline form of orifice, with its position relative to the blade. The charts shown in Figs. 10, 11, 12 and 13 serve to compare effect of different number of blades and various pitch ratios from 0.5 to 1.0. It will be noted that the volume increases with greater number of blades, but not in direct proportion. An empirical factor of $\sqrt[4]{B/2}$ is approximately correct, in which B is the number of blades. This will correspond to approximately 20 per cent more capacity with four blades as compared with two, and 30 per cent for six blades as with two.

The static pressure in the region of restricted deliveries will increase approximately in direct proportion to the number of blades for equal pitch ratios.

The horsepower curves are fairly flat for low pitch ratios, increasing toward restricted deliveries as the pitch ratio is increased, and slightly also as the number of blades is increased. This design characteristic requires no larger capacity motors for operation against resistances than for free delivery, except for six blade fans at the higher pitch ratios. In the latter case a moderate increase in the motor size of 25 per cent will suffice, except at low ratios of volume.

The mechanical efficiencies are quite similar for different numbers of blades at the same pitch ratios, the increase for four blades as compared to two being approximately two per cent, and a similar increase for six blades as compared to four. This difference in efficiency is somewhat at variance with published efficiency data on airplane propellers, which is based on thrust. In the case of ventilating fans additional blades serve to increase the coefficient of area of the effluent air stream. Due to these design characteristics it is possible to realize more favorable efficiencies at and near to free delivery, where most of these fans operate. The mechanical efficiencies which result from the prescribed method of computation, using the full area of the orifice for determining the average velocity and the velocity pressure, result in apparently higher relative efficiencies for restricted deliveries than for free delivery. Where the actual velocities and calculations are determined, it will be found that the efficiency curves tend to flatten out at the peak, giving the same relative advantages for increase in number of blades at correspondingly restricted conditions of operation as for free delivery. Computations of this kind raise the efficiency the greatest amount at free delivery, where the total head is all velocity pressure, whereas at all other points the velocity head becomes a relatively smaller proportion of the total pressure as the static pressure increases. (See Table 1).

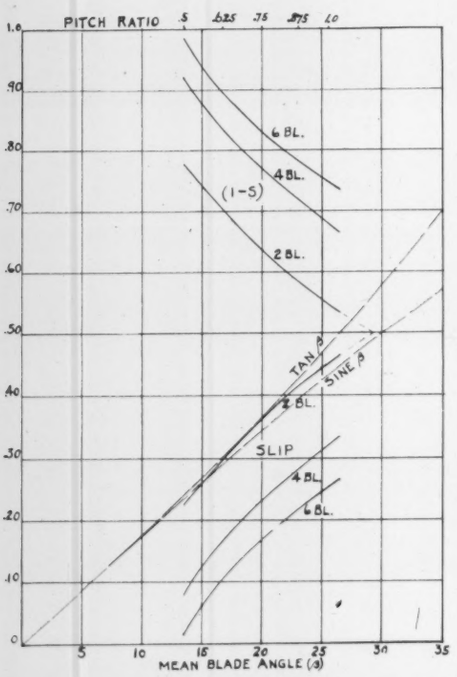


Fig. 14—Comparative curves of slip and pitch ratios for two, four and six blade fans

The static efficiencies, while not shown on the curves, will obviously be greater for low than for high pitch ratios.

The decreased efficiencies at higher pitch ratios would appear to reflect the importance of avoiding the disturbance to stream flow which accompanies higher angles of attack. The best pitch ratio will be found to be 0.75, corresponding to a mean blade angle at ⅔ radius of 20 deg.

In any propeller operating in air, as in water, there will be a certain slip. The geometrical pitch minus the slip is called the true pitch. This can be expressed thus:

$$True\ Pitch = Geometrical\ Pitch\ (1\text{-}Slip) \qquad (4)$$

The true pitch multiplied by the RPM gives the velocity or the distance the particle moves in one minute. The volume of air handled by the fan at free delivery may be expressed as follows:

$$CFM = 2/3\ \pi\ D\ N\ tan\ b\ A\ (1\text{-Slip}) \quad \text{where } A = \text{area of orifice} \qquad (5)$$

If the value $\frac{\pi D^2}{4}$ is substituted for A the formula is:

$$CFM = 1.645\ D^3\ N\ Tan\ b\ (1\text{-}S) \qquad (6)$$

If test results values of calculated slip are plotted against pitch ratios, or mean blade angles, or both, a series of curves will be obtained for two, four, and six blades as shown in Fig. 14.

In the case of the two blade fans the slip will be found equal to the tangent of the mean blade angle for optimum pitch ratios, and equal to the sine of the angle at pitch ratios below and above the optimum pitch ratios. These values may then be substituted in formula (6), and if greater accuracy is desired the following values of S may be used:

Mean Blade Angles 12 to 17 deg = *Sine b*
Mean Blade Angles 17 to 22 deg = *Tan b*
Mean Blade Angles 22 to 27 deg = (*Sine b* + *Tan b*) ÷ 2
Mean Blade Angles 27 to 32 deg = *Sine b*

For four and six blade fans the value of the slip may be determined from the chart, or the empirical value $\sqrt[4]{\frac{B}{2}}$ as previously mentioned may be used.

The formula is then applicable to any number of blades, and to all pitch ratios, or mean blade angles, covered by these data.

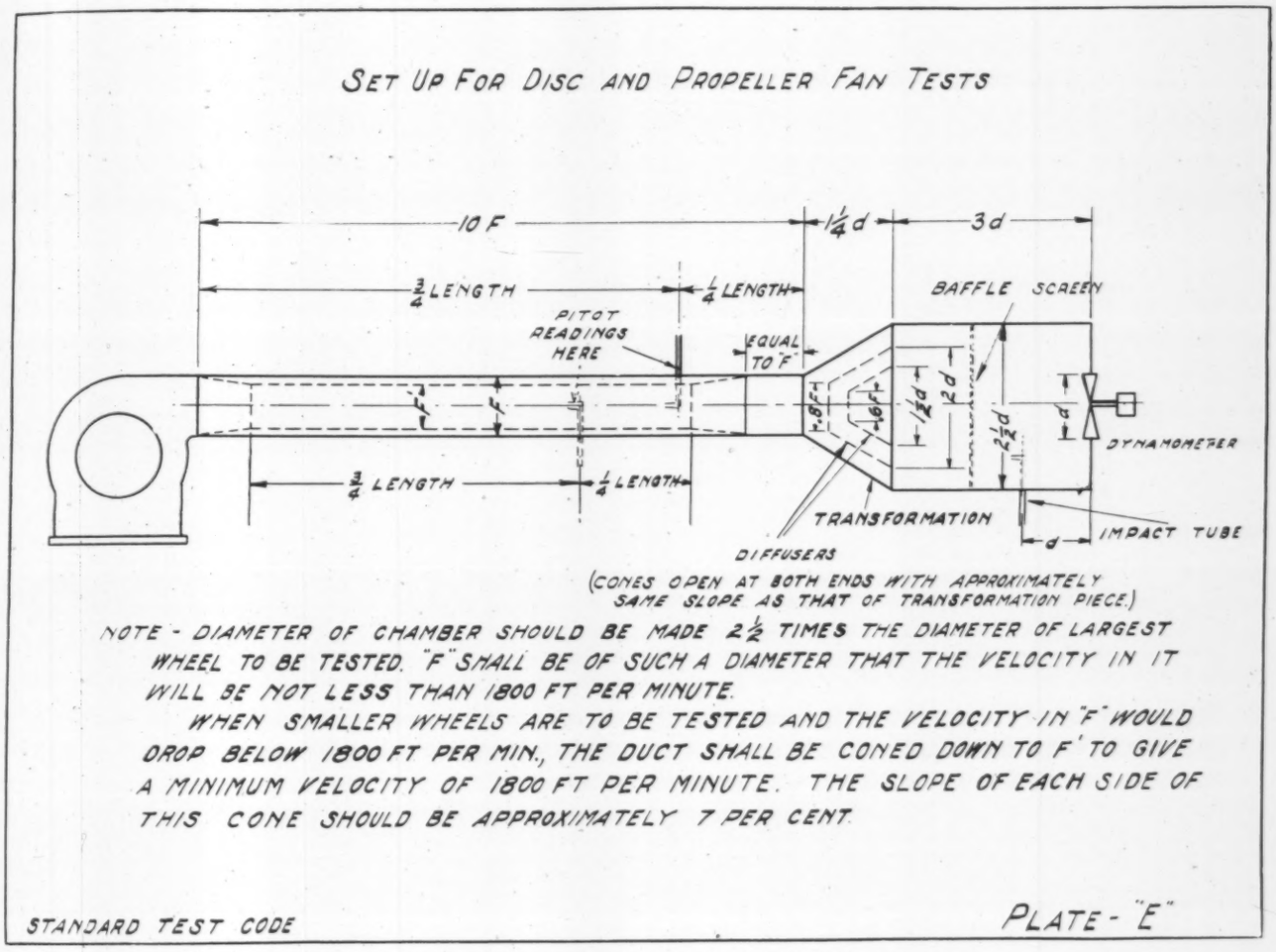

SET UP FOR DISC AND PROPELLER FAN TESTS
10 F
1¼ d
3d
¾ LENGTH
¼ LENGTH
BAFFLE SCREEN
PITOT READINGS HERE
EQUAL TO F
1.8F
1.6F
1½d
2d
2½d
d
DYNAMOMETER
¾ LENGTH
¼ LENGTH
TRANSFORMATION
d
IMPACT TUBE
DIFFUSERS
(CONES OPEN AT BOTH ENDS WITH APPROXIMATELY SAME SLOPE AS THAT OF TRANSFORMATION PIECE.)
NOTE - DIAMETER OF CHAMBER SHOULD BE MADE 2½ TIMES THE DIAMETER OF LARGEST WHEEL TO BE TESTED. "F" SHALL BE OF SUCH A DIAMETER THAT THE VELOCITY IN IT WILL BE NOT LESS THAN 1800 FT PER MINUTE.
WHEN SMALLER WHEELS ARE TO BE TESTED AND THE VELOCITY IN "F" WOULD DROP BELOW 1800 FT PER MIN., THE DUCT SHALL BE CONED DOWN TO F' TO GIVE A MINIMUM VELOCITY OF 1800 FT PER MINUTE. THE SLOPE OF EACH SIDE OF THIS CONE SHOULD BE APPROXIMATELY 7 PER CENT.
STANDARD TEST CODE
PLATE - "E"

Fig. 15—Diagram of standard test set-up for disc and propeller fans

(For ease in converting values of pitch ratio to corresponding mean blade angles reference is again made to the formula *Pitch Ratio* $= \frac{2}{3}\pi$ *Tan b.*)

All data presented herein are from tests made in accordance with the provisions of the Standard Test Code for Centrifugal and Propeller Fans. In Fig. 15 is shown a diagram of Plate E from the Test Code, and an illustration of the actual test set-up is shown in Fig. 16.

These performance data do not apply to all airplane or airfoil propeller fans, but only to the particular design herein presented, and having a blade of substantially constant width, except for the widening projection at the tip, as illustrated in Fig. 17.

The airfoil blades were cast of aluminum alloy from metal patterns and accurately finished to gages for correct airfoil section. They were then buffed and polished, care being taken to insure exact wheel balance without the use of any balance weights. Blade angles are established within $\frac{1}{5}$ of a degree at five stations equidistant from one-third radius to the tip.

The use of more favorable blade angles for efficient operation as compared to the more common practice with other types requires somewhat higher speeds for airfoil fans. However, the airfoil itself may be run at slightly higher speeds for equal quietness as compared either with thin plates or high pitch ratios. Referring to Figs. 5 and 6 it will be noted that each revolving blade must pass through the wake of the preceding blade. It is therefore important for quiet operation that the disturbance at the back of the blades be kept as small as possible.

With two blade fans at ordinary speeds there may be a noticeable flutter, due to the low frequency of the vibration. When an increased number of blades are used, this disappears, as the ear does not readily separate higher frequency sounds from all the several variable factors involved in the total noise volume. Within the limits covered by these tests it was found that better

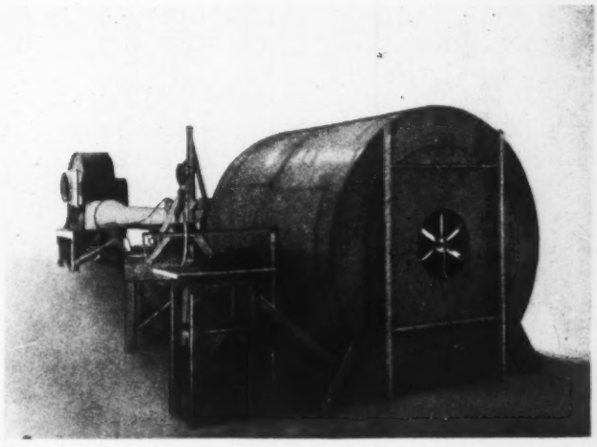


Fig. 16—General view of fan test apparatus

results may be accomplished with a greater number of blades, even though a slightly higher decibel rating may result. A four blade airfoil fan is shown in Fig. 17 and a six blade direct connected fan unit in Fig. 18.

The same judgment is necessary in applying these fans as with any other type where quiet operation is required. Generally low blade velocities tend towards quietness, and high velocities towards noise. Quiet motors with resilient mountings and sleeve bearings are used for best results. When capacitor motors are used, additional speeds are available with a slight additional expense as compared to single speed motors.

In many of the industrial applications, where the noise level of the environment is relatively higher, usual standard motor speeds, windings, and ball bearings may be used.

Conclusions

The ordinary airplane propeller is inherently unsuited for use as an efficient ventilating fan without modification of either its form of blade tip, or the orifice ring, or both.

The contraction of the air stream increases the velocity head loss. Increasing the coefficient of area of the air stream raises the mechanical efficiency.

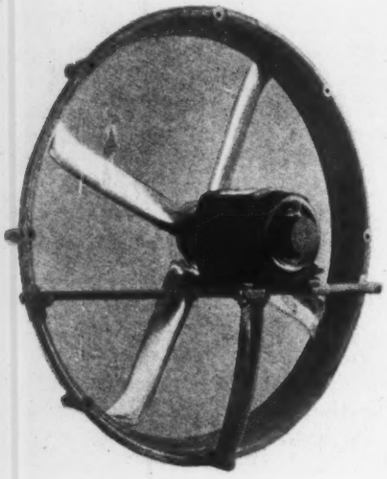


Fig. 17—Four blade airfoil fan

Streamline orifices, more effective forms of blade tips, and a greater number of blades all tend to increase the efficiency.

The use of a short discharge duct eliminates swirl at blade tips, recovers some velocity head, and increases the capacity and the mechanical efficiency.

Variable blade pitch is better than constant pitch and moderate pitch ratios of 0.75 are the optimum.

An increase in the number of blades increases the capacity as the fourth root of the number ratio, the static pressure more nearly in direct proportion to the number, and the mechanical efficiency slightly.

With airfoil blades high mechanical efficiencies may be realized and especially in the region of free delivery where the majority of these fans operate.

Two blade fans are not as quiet as four or six blades because of the low frequency vibration causing a noticeable flutter.

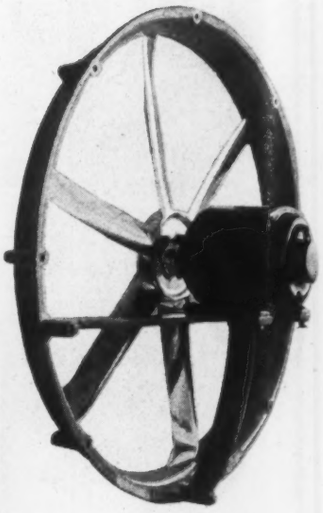
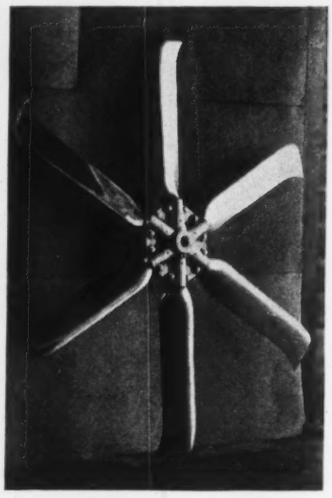


Fig. 18—Six blade airfoil fans



Fans with airfoil blades have non-overloading horse power characteristics except with multi-blades having pitch ratios above the optimum.

Airfoil fans conform to *Fan Laws,* in relation to capacity, pressure, and horse power when the speed, air density, or size is changed. As the great majority of these fans operate at, or near, free delivery, and are frequently only so rated, these *Fan Laws* are very helpful in calculations concerned with the selection and application of fans.

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The Performance of Propeller Fans, by A. I. Brown, *Ohio State University Studies Engineering Series,* Vol. 11, No. 3, Part 1, May, 1933.

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The Design and Performance of an Axial-Flow Fan, by L. S Marks, Harvard University, and J. R. Weske, *A.S.M.E. Transactions,* 1935.

Simple Aerodynamics and The Airplane, by C. N. Monteith, U. S. Air Service, McCook Field, Dayton, Ohio.

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Air Conditioning Course

An evening course in Air Conditioning is offered by the Extension Departments of Architecture and Mechanical Engineering of Columbia University in the City of New York. The sessions will occur two evenings a week from February 5 to May 20, 1936, and the fees are $5.00 for registration and $30 for tuition.

John Everetts, Jr. will conduct the classes and among the subjects of discussion will be study of steam-air mixtures with relation to comfort cooling and commercial air conditioning; comfort cooling calculation, general study of equipment and design, and comparative analysis of refrigerating equipment and refrigerants used in connection with air conditioning.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS is located

Report of the Committee on Research for 1935

By **A. P. Kratz* and F. C. Houghten†**

THE Committee on Research of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS held four meetings during the year. At the first meeting, held in Buffalo on January 28, a budget for 1935 was prepared and other business pertaining to the 1934 committee was completed. The 1935 committee met immediately following adjournment of the 1934 committee, approved the budget recommended by the previous committee, and adopted a research program. Two meetings of the Committee were held in Toronto, Ontario, during the Semi-Annual Meeting of the Society, at which time the work of the various Technical Advisory Committees and the studies carried on under them at the Laboratory in Pittsburgh and in the co-operating universities were reviewed.

The Committee operated under a budget somewhat larger than the previous year, and found no great difficulty in meeting its requirements. The funds on hand at the close of the year are greater than those on hand when the Committee was organized.

Sixteen Technical Advisory Committees served as sub-committees of the Committee on Research, each to consider a separate technical subject which it studied or outlined for laboratory investigation. Three new Technical Advisory Committees on (1) Summer Cooling Standards, (2) Frictional Resistance to Flow of Air in Small Ducts and Fittings, and (3) Corrosion in Air Conditioning Equipment, were appointed, and the work of determining summer cooling standards was placed on the Research Laboratory's program for immediate investigation.

An extensive program of research was carried on at the Laboratory in Pittsburgh and in cooperation with nine universities. These activities resulted in 11 technical papers presented to the Society, and the development of a code on Garage Ventilation which was formally adopted as a standard of the Society by letter ballot of the membership.

The Committee on Research has always considered it desirable to keep in contact with the Society through the various chapters, and also to keep in contact with other organizations who should be interested in its work. It regretted the necessity of curtailing this activity during the depression because of insufficient funds. With improved conditions during the current year it was possible to re-establish this practice in a small way. The Chairman of the Committee attended three chapter meetings and the Director of the Laboratory attended two chapter meetings at which the work of the Committee was discussed. Contacts with other technical groups were continued wherever possible. It is hoped that this activity may be increased in the future.

RESEARCH LABORATORY
AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
STATEMENT OF INCOME AND EXPENSES
YEAR ENDING DECEMBER 31, 1935
RESEARCH FUND (Unrestricted)

INCOME		
Contribution from General Fund as provided in By-Laws—40% of dues collected from Members and Associate Members		$ 9,172.76
Appropriations:		
From General Fund	$1,500.00	
From Endowment Fund	662.50	
		2,162.50
Contributions from outside sources		5,798.36
Interest on bank deposit		68.00
		$17,201.62

*Chairman, A. S. H. V. E. Committee on Research; and, Research Professor, Department of Mechanical Engineering, University of Illinois, Urbana, Ill.
†Director, A. S. H. V. E. Research Laboratory, Pittsburgh, Pa.
Presented at the 42nd Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Chicago, Ill., January, 1936.

EXPENSES:		
Salaries:		
Laboratory staff	$6,620.00	
Graduate Student help	1,187.00	$7,807.00
Cooperative research contracts		6,148.36
Special fellowship at University of Illinois Medical School		450.00
Correlative thermal research		500.00
Laboratory supplies and equipment		438.50
Travel		501.88
Printing and promotion		215.00
Exhibits and meetings		135.36
Office supplies, equipment and expense		311.08
		16,507.18
Excess for year of income over expenses of Research Fund (Unrestricted)		$ 694.44

1935 Research Contributors

Contributing Funds:

Armstrong Cork Products Co.
Crane Co.
C. A. Dunham Co.
Heating, Piping & Air Conditioning Contractors National Association.
Modine Manufacturing Co.
Penn Electric Switch Co.
Portland Cement Association.
Trane Co., The.
A. C. Willard.

Contributing Equipment:

Aerofin Corp.
American Radiator Co.
Detroit Lubricator Co.
Julien P. Friez and Sons, Inc.
Frigidaire Div., General Motors Corp.
General Electric Co.
Illinois Testing Laboratories, Inc.
Johnson Service Co.
Meyer Furnace Co., The.
Minneapolis-Honeywell Regulator Co.
National Warm Air Heating and Air Conditioning Association.
John J. Nesbitt, Inc.
Weil-McLain Co.
York Ice Machinery Corp.

Universities Cooperating with the Committee on Research

1. AGRICULTURAL & MECHANICAL COLLEGE OF TEXAS: Heat Requirements of Buildings.

2. CASE SCHOOL OF APPLIED SCIENCE: Heat transfer from and to direct and extended surfaces with forced air circulation.

3. CORNELL UNIVERSITY: Heat requirements of buildings.

4. HARVARD SCHOOL OF PUBLIC HEALTH: Minimum air requirements for ventilation.

5. UNIVERSITY OF ILLINOIS: (1) Direct and indirect radiation with gravity air circulation. (2) Cooling of buildings in summer. (3) Air conditioning in the treatment of diseases.

6. MICHIGAN COLLEGE OF MINING AND TECHNOLOGY: Corrosion in return lines in relation to the chemical composition of the water, vapor and gas handled.

7. MARQUETTE UNIVERSITY: Methods of air supply and distribution in air conditioning.

8. UNIVERSITY OF MINNESOTA: (1) Dust and dust control apparatus. (2) Heat transmission through concrete walls.

9. UNIVERSITY OF WISCONSIN: Heating of buildings.

Papers Resulting from Research During 1935

Eleven technical papers, resulting from research carried on in Pittsburgh or in the cooperating universities under the several Technical Advisory Committees were prepared for presentation at meetings of the Society and publication in the A. S. H. V. E. JOURNAL (in *Heating, Piping and Air Conditioning.*) They are listed below and will be referred to by number in the discussion of research projects later in this report.

1. A Carbon Monoxide Alarm and Ventilation Control, by F. C. Houghten and Linwood Thiessen; March, 1935.
2. Classroom Odors with Reduced Outside Air Supply, by F. E. Houghten, H. H. Trimble, Carl Gutberlet and Merle F. Lichtenfels; May, 1935.
3. The Dust Problem in Air Conditioning, by F. B. Rowley, June, 1935.
4. Air Supply to Classrooms in Relation to Vent Flue Openings, by F. C. Houghten, Carl Gutberlet and Merle F. Lichtenfels; June, 1935.
5. Oil Burning in Residences, by D. W. Nelson; July, 1935.
6. Classroom Drafts in Relation to Entering Air Stream Temperature, by F. C. Houghten, H. H. Trimble, Carl Gutberlet and Merle F. Lichtenfels; July, 1935.
7. Comfort Standards for Summer Air Conditioning, by F. C. Houghten and Carl Gutberlet; November, 1935.
8. Performance of Fin-Tube Units for Air Heating, Cooling and Dehumidifying, by G. L. Tuve; December, 1935.
9. Thermal Properties of Concrete Construction, by F. B. Rowley, A. B. Algren and Clifford Carlson; January, 1936.
10. Ventilation Requirements, by C. P. Yaglou, E. C. Riley and D. I. Coggins; January, 1936.
11. Corrosion Studies in Steam Heating Systems, by R. R. Seeber, F. A. Rohrman and G. E. Smedberg. To be presented at the Annual Meeting; January, 1936.

Research Projects Investigated During 1935

During the year 16 projects were given consideration under as many Technical Advisory Committees. Because of the budget limitations, laboratory research, either at the Laboratory in Pittsburgh or at the cooperating universities, was possible in only a few cases; however, the Technical Advisory Committees were in most cases successful in giving consideration to the subject in hand with measured progress. The personnel of each of the Committees, working under the Committee on Research, and the work carried on under them during the year are given below.

1. AIR CONDITIONS AND THEIR RELATION TO LIVING COMFORT

C. P. Yaglou, *Chairman*

J. J. Aeberly — R. R. Sayers
W. L. Fleisher — C.-E. A. Winslow

The committee has continued a study of the minimum ventilation requirements for health and comfort. The cooperative laboratory investigation of the subject was carried on at Harvard School of Public Health. This work will be continued another year if resources allow. A progress report[10] is to be presented at the Annual Meeting, giving ventilation requirements of various groups of school children and adults under representative practical conditions. The report shows clearly the impossibility of fixing any single standard that would apply under all conditions. Each case, it would seem, must be considered on its own merits. The important factors appear to be personal sanitation, air space allowed per person, and odor removing capacity of air conditioning processes. The range in outdoor air requirements is from 5 cfm per person, or less, when the air is completely conditioned, to 38 cfm in the case of grade school children of the poorest class, when the air is not conditioned.

Considerable evidence is adduced to the effect that there are other factors in the ventilation of occupied rooms, besides temperature and humidity which affect the quality and pleasantness of air from the point of view of both occupants and visitors. This evidence confirms from a different angle an old conclusion of the New York State Commission on Ventilation, and also the very latest finding of Winslow on *weather feelings.*

Another activity of the committee during the past year was a critical review of the literature on carbon dioxide, humidity and ozone, supplemented by a number of tests at Harvard, for the purpose of finding out where information is inadequate and whether there is sufficient justification for additional research.

The Research Laboratory in Pittsburgh reported a brief study[2] of the odor conditions resulting with reduced ventilation in classrooms in connection with a study of school room ventilation under

the Technical Advisory Committee on Minimum Temperature and Method of Introduction of Cooling Air in Classrooms.

2. AIR CONDITIONING IN THE TREATMENT OF DISEASES

E. V. Hill, *Chairman*

N. D. Adams
J. J. Aeberly
Margaret Ingels
H. R. Linn
P. J. Marschall
E. L. Stammer

This committee was appointed a year ago to develop cooperation with medical schools in a study of the relation of air conditioning to the treatment of diseases. The committee has been active in giving consideration to the problem throughout the year and was successful in developing a cooperative arrangement with the College of Medicine of the University of Illinois in Chicago, under which a comprehensive study will be carried on. Complete details of the testing program have not been decided upon at present, but it is proposed first to study a group of normal individuals when subjected to various atmospheres with temperatures ranging from 50 to 100 F and relative humidities ranging from 20 per cent to 60 per cent or more.

A number of different studies have been proposed to measure the body's behavior under these atmospheric conditions. These are:

(1) Mental tests involving various functions and determined somewhat by the subject's educational background.
(2) Circulatory tests giving the state of blood circulation under basal conditions consisting of complete physical and mental relaxation, a period of 12 to 18 hours post-prandial, and freedom from all drugs. The following tests would be made:
   a. Metabolic rate, including respiratory quotients.
   b. Oxygen saturation of arterial blood and oxygen capacity.
   c. Analysis of alveolar air, vital capacity. Study of character of respiration.
   d. Circulation time.
   e. Cardiac output.
   f. Blood volume blood counts; total fluid content.
   g. Reaction of skin to salt solutions, an index of its hydrophilic properties.
   h. Capillary and venous pressure.
   i. State of capillaries and smaller blood vessels as tested by the plethysmograph and skin temperature.
(3) Studies of appetite, gastro-intestinal behavior, and hunger contraction might be added.

Either subsequent to or at the same time that studies are made on normal patients it is planned to study the effect of air conditions on patients having the following circulatory disorders:

(1) Toxic goiter.
(2) Rheumatic heart which is on the border line of decompensation.
(3) Rheumatic heart which is compensated.
(4) Compensated hypertensive heart.
(5) Hypertensive heart on the border line of decompensation.

3. ATMOSPHERIC DUST AND AIR CLEANING DEVICES

H. C. Murphy, *Chairman*

J. J. Bloomfield
M. I. Dorfan
Philip Drinker
Leonard Greenburg
S. R. Lewis
F. B. Rowley
D. C. Simpson
W. O. Vedder

Since the last Annual Meeting the Committee has continued its studies and investigations looking to the development of a code for testing and rating air cleaning devices used in dust hazardous occupations. Much work has been conducted by correspondence, with such incidental meetings as were possible at the National Safety Congress and similar engineering assemblages, and through cooperation between the Director of the Laboratory and the U. S. Bureau of Mines, as an aid in the development of a code.

The Chairman spent some time in England during the past Summer, and had an opportunity of studying the work being done there in correcting atmospheric pollution. The officers and members of the *Institution of Heating and Ventilating Engineers of Great Britain* were courteous and cooperative, and gave every possible assistance in these investigations.

Many considerations recommended further careful and detailed study before recommendations for the proposed code are submitted to the Society, and it is hoped that definite procedures can be submitted for consideration at the June Meeting.

4. COMFORT STANDARDS FOR SUMMER COOLING

W. L. Fleisher, *Chairman*

A. E. Beals
E. R. Bichowsky
Elliott Harrington
E. V. Hill
C. P. Yaglou

This is a new committee appointed during the year to undertake a study of comfort standards for summer cooling. A great deal of dissatisfaction was found by the committee in the profession and industry with the present standards as contained in the A.S.H.V.E. GUIDE.

A preliminary survey of the entire subject was outlined by the Committee and carried out by the Research Laboratory during the summer months. While this study was in no respect conclusive as establishing finally acceptable standards, it accomplished a great deal in indicating what may be expected as a result of further study. A paper resulting from this work is being presented[r] at the Annual Meeting.

Additional work was carried on by the Chairman of the committee, dealing with possible rise in temperature with higher air velocities and maximum relative humidities along effective temperature lines outside the so-called comfort zone.

The studies so far made have not only served to conclusively demonstrate that the present standards are unnecessarily limiting, but they have further served to point out the need for thorough investigation of several phases of the subject. Among the different factors which may possibly affect the final establishment of summer cooling standards and which are recommended by the committee for further study are the following:

(1) A more definite upper limitation in allowable relative humidity at the proper effective temperature.
(2) Variations in the desirable effective temperature based upon the daily prevailing outside condition from which persons enter a conditioned room.
(3) Variations in the desired indoor effective temperature based upon the average climatic condition outdoors, based not on daily change but upon an average over a much longer period of time, or in other words, the variation in desired indoor effective temperature based upon the summer climatic condition for a given city or region; usually fixed by latitude.
(4) Variations in the indoor effective temperature desired by persons of varying sensitivity, including older persons and persons with lower vitality.
(5) A study of the conditions which may be interpreted by a person as a draft, as determined by excessive air motion at the prevailing indoor temperature, and for air streams of other temperatures, usually streams of entering cooler air which may strike a person.
(6) A study of the physiological reactions of a person before, upon entering, during occupancy, immediately upon leaving, and over an hour or two after leaving a cooled room, particularly observing the changes in skin temperature on various parts of the body, and perspiration.

A discussion of these items is given.

(1) *A More Definite Upper Limitation in Allowable Relative Humidity:* A series of tests should be made in which the main purpose would be to determine the relative effect on persons entering a cooled room at the same effective temperature from the same outside conditions, when the relative humidity or moisture content of the cooled room varies. The study of last summer indicated no variation whatever for relative humidities as high as 70 per cent, and no outstanding variation for relative humidities as high as 85 per cent. The only way in which such effects can be determined satisfactorily is to make a series of tests with sufficient number of the variables controlled so that the variations due to this one factor may be determined. Perhaps 12 to 15 or 20 tests would be conclusive in settling this point.

(2) *Variations in the Desirable Effective Temperature Based Upon the Daily Prevailing Outside Conditions:* Last summer's

study indicated no marked or outstanding variations desired by the subjects. However, since other variables, such as the indoor relative humidity, length of exposure, degree of perspiration, etc., were not controlled, the data were not voluminous enough to draw any closely determined conclusions regarding possible small variations in the desired indoor effective temperature.

(3) *Effective Temperature Variations Desirable for Indoor Cooling for Regions of Different Climatic Conditions:* The study made last summer could not in any sense answer this question, which is of interest to a great many air conditioning engineers who operate throughout different geographical locations of the country. That the summer climatic condition of a given region must necessarily affect the desired indoor conditions for summer cooling may be accepted as axiomatic, from the fact that for winter heating an effective temperature range of from 63 to 71 deg is desired, while for summer cooling an effective temperature range of from approximately 71 to 74 was indicated for the Pittsburgh locality during last summer. Certainly with less severe summer conditions than pertaining in Pittsburgh, summer cooling would require some intermediate effective temperature range. It might be argued with equal logic, that for regions having more severe summer climates, as an example, New Orleans, La., or Dallas, Tex., a higher effective temperature range for indoor summer cooling would be required.

One significant fact brought out in last summer's study, however, leads to the belief that the desirable indoor effective temperature range for summer cooling may not go any higher than that found for Pittsburgh, in spite of higher outside temperatures. The desirable effective temperature range for indoor cooling in Pittsburgh last summer was found to have an upper limit but a degree or two lower than the perspiration line. Since it may be accepted as axiomatic that summer cooling conditions must not result in sensible perspiration, it would follow that the upper limit of the effective temperature range for any region could not go higher, unless the perspiration line also moves upward with different climatic conditions. Perspiration being a fundamental physiological reaction, it would seem unlikely to occur at varying effective temperatures based upon climatic conditions, although this fact has not been established. This phase of the subject should be next studied by selecting a minimum of two additional localities, one in a hotter region near the Gulf Coast, and one in a cooler region, such as Toronto, Ontario. If two such localities as New Orleans and Toronto should be studied next summer and the results compared with those found at Pittsburgh, it should be possible to more definitely establish the fact that climatic variations require variations in desired effective temperatures for summer cooling. If Pittsburgh and these other two localities show little variation, then the subject could be dropped; on the other hand, if these three localities should show a wide variation, then it might be desirable to extend the study to other localities having different summer climates.

(4) *Variation in Age and Sensitivity of Persons in Relation to Summer Cooling:* Undoubtedly, the conclusiveness of the Laboratory's study last summer can be criticized most because of the fact that the subjects were young, rugged men. In this connection, it is well to point out that this criticism was anticipated before last summer's study was made, and that the criticism of the Laboratory's work last summer is not so much the finding of fault in the plan followed by the Laboratory as it is a criticism of using the results as conclusive until further work is done. It was agreed that it was desirable to make the preliminary survey with persons not supersensitive to summer cooling, and then later to study variations from these basic findings. It is certain, however, that additional work should be done to show variations resulting from variations in age and sensitivity in individuals. Those associated closely with the work are inclined to believe that those conditions which the young subjects classed as *comfortable,* or at (4) in the test scale, will not be uncomfortable to most older and more sensitive people. It is thought that the difference will rather lie in the ability of different age groups to stand lower temperatures without undue discomfort. As an example, it may be expected that all age groups will be comfortable in the same effective temperature range in which the young subjects were comfortable, but that while the young subjects experienced no great discomfort at effective temperatures of 70 deg and lower, but simply voted that they felt *cool,* older persons will not only feel *cool* but they will feel decidedly uncomfortable. This is, of course, only a conjecture, and further study will prove it either true or false. If, however, this conjecture is true, this phase of the problem can be easily disposed of; on the other hand, if it is not true and it is found that different age groups desire different effective temperature ranges, then a final solution of the problem will be difficult to find.

(5) *Drafts in Cooling:* The question of what constitutes objectionable drafts is always a vital question when cooled air is admitted to a room, or when cooling is applied otherwise. Considerable work has been done on what constitutes allowable air motion within occupied space in heating practice. Many are of the opinion that these same limitations apply to summer cooling. It is almost certain that they do not apply to the same extent. In fact, it is probable the air movement in summer cooling can be used as a considerable factor in reducing the sense of warmth. To be so used, however, air movement must necessarily be uniform so as not to produce excessive cooling of any localized parts of the body. While, as mentioned above, there is considerable data on the subject of allowable air velocities in occupied space at, for example, 70 F during the heating season, these velocities must be uniform and of the same temperature as the uniform room temperature.

There is perhaps as little data available on the subject of what constitutes a draft in heating practice as in cooling practice. Therefore, aside from the question of determining what are allowable uniform air movements in a room for cooling when this air velocity is accounted for in the effective temperature, it is desirable to make a study of cold drafts as such, both for such temperatures as are used in heating and in cooling. This problem is one and the same, and should be carried on as applying to both heating and cooling. The greatest difficulty that the Laboratory had in its study of Minimum Temperature and Method of Introduction of Cooling Air in classrooms last winter was in determining what a draft was. Undoubtedly, a draft is one of the most discussed phenomena considered by the heating, ventilating and air conditioning engineer, and yet, to date there has been no effort to determine what combinations of air movement and temperature constitute a draft.

Since this phase of the study is most fundamental to the entire heating, ventilating and air conditioning industry, as well as to the study of summer cooling standards, it should be carried on at once. At least most phases of the study can be carried on without respect to winter or summer, and it is suggested that the Laboratory proceed with this phase of the study at once. In making the study, means should be set up in the psychrometric rooms for producing a localized area of rather constant, linear air movement, the temperature of which can be controlled, irrespective of the surrounding more or less uniform room temperature. Arrangements should be such that this uniform air velocity of known temperature and speed may be directed against various parts of the body, including the top of the head, the back of the neck, the back, the thigh and the ankles. The study probably will not be difficult nor require a great deal of time.

(6) *Physiological Effects on Entering, Occupying and Leaving a Cooled Room:* In order to have a better understanding of what takes place when a person receives a shock upon entering a cooled space or a *relapse* upon reentering the hot outside, it is desirable to make a brief study of such physiological reactions as skin temperature and perspiration effects during such changes. Many persons are talking about skin temperature effects without knowing much about what they are and the variations met with under the changes referred to previously. This phase of the study will not be long, and at least a large part

of it can be carried on either during the winter or summer. In fact, some of the results may be gleaned from a further analysis of data available at the Laboratory and collected several years ago.

(7) *Physiological Reactions to Air Conditions Which May be of Value in the Treatment of Diseases:* During the past few months the Laboratory, working under this committee, has developed a friendly cooperation with medical staff at the University of Pittsburgh. The committee is particularly happy over the fact that these members of the medical profession came to the Laboratory with their problem, as a result of the Laboratory's papers of a physiological nature published over the past several years.

These members of the medical staff are giving particular attention to the treatment of certain diseases by subjecting the individual to certain definitely controlled atmospheric conditions, particularly pertaining to atmospheric temperature. A few years ago the Laboratory made its psychrometric rooms available for the treatment of a few syphilitic patients. As a result of this study, it was rather conclusively proven that syphilis could be cured by subjecting the patient to a high temperature atmosphere. This cure seemed to be equivalent to the prevailing cure by giving the patient malaria fever. Probably the only advantage in the malaria fever treatment was the high body temperature resulting. Following these disclosures, the question arose as to whether the high body temperature killed micro-organisms within the body directly, or whether the high temperature brought the effect about indirectly by increasing the white blood cell or leucocyte count of the blood, which is recognized as a measure of the ability of the body to throw off infections.

The Laboratory recently cooperated with the medical staff at the University of Pittsburgh in making the psychrometric rooms available for studies of the effect of high temperature of the body on its blood count, and in which members of the Laboratory personnel acted as subjects. It was found that upon raising the body temperature 104 F in a saturated atmosphere of 110 F, the leucocyte count of the blood was, during the same period of time, increasing from about 5,000 to about 14,000, hence definitely establishing the fact that the high temperature does immediately change the leucocyte count of the blood.

Whether or not these developments will have far reaching effects in the treatment of diseases by air conditioning remains to be seen. However, it at least opens up a very extensive and most interesting range of possibilities. The Laboratory has been asked to collaborate with the University in preparing a paper on the brief findings mentioned.

5. CORROSION IN AIR CONDITIONING EQUIPMENT

A. E. Stacey, *Chairman*
M. S. Kice
F. N. Speller
C. M. Sterne
R. T. Thornton
J. H. Walker

This committee was appointed in the late summer to undertake a study of corrosion problems in air conditioning equipment. The committee has since been actively engaged in formulating a program. While a complete program has not yet been completed, the committee is at the present time studying the seriousness of the corrosion problem in general, the prevailing conditions surrounding locations of serious corrosion, the metals involved, and whether the corrosion results from contact with the atmosphere or water. The committee is giving further consideration to atmosphere contamination which may result in corrosion, the characters of water which may result in corrosion of metals in contact with it, and possible treatment of such water in order to improve conditions. Consideration is also being given to the effectiveness of protective coatings in reducing corrosion. In studying the seriousness of the corrosion problem in order to determine whether research is desirable, the committee is giving thought to air conditioning equipment which may be included in several different types, which based upon usage may react differently as regards corrosion.

6. CORROSION IN HEATING SYSTEMS

J. H. Walker, *Chairman*
E. L. Chappell
W. H. Driscoll
C. A. Dunham
L. B. Miller
R. R. Seeber
C. M. Sterne

This committee was organized to cooperate with the Michigan College of Mining and Technology in a study of corrosion of ferrous metals in heating systems. A research project has been under way at that institution since June, 1933. A preliminary report was presented to the 1934 Annual Meeting by Prof. R. R Seeber. A second report[11] will be presented at the Annual Meeting. The results give promise of throwing considerable light on the knowledge of corrosion in heating system return lines and methods of reducing it. Up to the present time the work has been financed entirely by the college, but it is hoped to obtain financial support from industry during 1936.

While the committee was originally organized to study corrosion of ferrous metals only, in heating systems, there has been a persistent demand that it also give consideration to corrosion of copper and copper bearing alloys in such systems. Consideration was given to this phase of the subject during the year. A questionnaire was sent out to a number of persons interested in the subject, and later this information was surveyed and discussed at a conference during the Semi-Annual Meeting. At this conference there was considerable interest shown in the problem, but there was no unanimous agreement concerning the need of such a study, it being contended by some that the corrosion resulting from the use of copper and copper bearing alloys in heating systems was so slight in comparison with corrosion of ferrous metals as to be negligible. Others reported considerable trouble from such corrosion, while others argued that the decreased thickness of copper and copper bearing alloys used might more than offset the decreased rate of corrosion. Another conference on the subject was arranged for and held in New York on Tuesday, December 3, attended by 13 engineers interested in the subject and representing 12 different organizations. No plans for future action were arrived at, but it was agreed that continued consideration of the subject was desirable.

7. DIRECT AND INDIRECT RADIATION WITH GRAVITY AIR CIRCULATION

H. F. Hutzel, *Chairman*
M. K. Fahnestock
H. R. Linn
J. P. Magos
J. W. McElgin
J. F. McIntire
T. A. Novotney
R. N. Trane

The committee continued to give consideration to the subject during the past year and active research was continued at the University of Illinois, in spite of limited funds. Two investigations are being made, neither of which is completed, but final reports may be expected for the Semi-Annual Meeting.

The work in the warm wall test booth consists of a study of the inlet and outlets of convector heater cabinets with reference to their effect upon the heat output or capacity of the units, in an attempt to arrive at definite recommendations as to the optimum dimensions for such openings in terms of the free area through the heating unit or the cross-section area of the cabinet. Three convectors, each having a different type of heating unit, are being tested. This program is approximately 30 per cent completed and the results indicate that there is an optimum inlet and outlet arrangement for a given cabinet and heating unit combination and that a variation from this optimum, especially in the case of the outlet, will materially reduce the heat output.

In the room heating testing plant an investigation is being made to determine the rate at which a room cools and heats with different types of radiators and convectors. This involves the effect on room air temperatures of the residual heat stored in cast-iron and non-ferrous convectors and cast-iron radiators when the steam supply is shut off. Four convectors, two having cast-iron heating units and two having non-ferrous heating units, and two types of cast-iron radiators are being tested. This investigation is nearly completed and it is anticipated that the results will be presented at the Semi-Annual Meeting.

Immediately following the completion of the program it is planned to undertake a brief study of the effect of insulating, first, the ceiling and then both the exposed walls and ceiling, of the test room in the room heating testing plant. This study will involve a comparison of the steam condensation and the room temperature conditions with the room uninsulated, with the ceiling insulated, with the ceiling uninsulated and with both walls and ceiling insulated.

8. EFFECT OF ENTERING TEMPERATURE AND VELOCITY ON THE TEMPERATURE AND DISTRIBUTION OF AIR WITHIN AN ENCLOSURE

C. H. Randolph, *Chairman*

E. H. Baars	J. E. Schoen
J. S. Jung	Ernest Szekely
F. A. Kartak	J. H. Volk

The committee completed plans for the study to be carried on in cooperation with Marquette University at Milwaukee. Suitable space was made available and a few preliminary tests were made.

9. FRICTIONAL RESISTANCE TO FLOW OF AIR IN SMALL DUCTS AND FITTINGS

J. H. Van Alsburg, *Chairman*

C. A. Booth	L. B. Miller
S. H. Downs	L. E. Smith

This committee was appointed during the present year to make a study of the frictional resistance to the flow of air in ducts, elbows and other fittings of small size, such as are finding wide application at the present time in air conditioning and heating systems in small buildings, and particularly as used in fan-furnace systems.

The committee has given considerable study to the problem and has outlined a program to be followed by the Laboratory in Pittsburgh, including the building up of a test set-up in which the frictional resistance to the flow of air may be studied in ducts and fittings of various sizes and design. This work is now being actively taken up by the Laboratory.

10. GAS HEATING

W. E. Stark, *Chairman*

R. M. Conner	Thomson King
C. A. Dunham	J. F. McIntire
Robert Harper	E. L. Tornquist
E. A. Jones	H. L. Whitelaw

This committee is continuing to give consideration to problems connected with the use of gas in central heating systems. No projects have been outlined requiring laboratory study beyond those being investigated by the testing laboratory of the *American Gas Association.*

11. HEAT REQUIREMENTS OF BUILDINGS

D. S. Boyden, *Chairman*	G. L. Larson
P. D. Close	H. H. Mather
W. H. Driscoll	E. C. Rack
H. M. Hart	F. B. Rowley
P. E. Holcombe	R. J. J. Tennant
V. W. Hunter	J. H. Walker

The Committee on Heat Requirements of Buildings, appointed two years ago for the purpose of developing a more rational understanding of the factors affecting the heating requirements of buildings, has continued to be active during the past year. Although several research projects dealing with certain phases of the subject are being studied, their effort in arriving at a final solution of the problem has proven extremely slow, largely for the reason that a study in a given building under definitely prescribed conditions must be continued throughout an entire heating season to be of any value whatever. Further, no one such study can be relied upon as a basis for a rational understanding of the complicated problem, but must rather be considered as one link in a long chain of evidence which must be completed before a final solution and conclusive report can be made by the committee. Invariably, however, all the evidence being analyzed by the committee tends to indicate that our present methods of estimating heat losses from buildings give values greater than those established by test. The real purpose of this committee is to eliminate the discrepancy. In attacking its problem, the committee has had the close cooperation and support of the *National District Heating Association,* the *American Gas Association,* the *National Warm Air Heating and Air Conditioning Association,* and others interested in the heating requirements of buildings.

During the life of the committee the following reports, resulting from definite concrete studies, have been presented, each of which has been helpful in solving the committee's problem:

1. Selecting Temperatures and Wind Velocities for Calculating Heat Losses, by P. D. Close. A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934.
2. Influence of Stack Effect on the Heat Loss in Tall Buildings, by Axel Marin. A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934.
3. Wind Velocities Near a Building and Their Effect on Heat Loss, by F. C. Houghten, J. L., Blackshaw and Carl Gutberlet. A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934.
4. Tests of Three Heating Systems in an Industrial Type of Building, by G L. Larson, D W. Nelson and John James. A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning,* November, 1934.
5. Heat Requirements of Buildings, by J. H. Walker and G. H. Tuttle. A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning,* December, 1934.

During the current year the committee has had several projects under consideration. In some cases these projects have resulted in reports for presentation at the Society's meetings, while in other cases, the projects have reached various stages of completion. These will be discussed as follows:

Heating Requirements—Sibley Dome, Cornell University: The committee, working with the Laboratory in Pittsburgh, cooperated with the Cornell University through H. M. Ward of the Department of Buildings and Grounds, and Perry West, acting as consultant for the University, and perfected plans for a comprehensive study of the various factors affecting heat losses from Sibley Dome, one of the buiidings of the University. Data were collected under Mr. Ward's direction throughout the past heating season, giving a daily record of the steam consumption together with temperatures in various parts of the building, the character of building occupancy, and the outside temperature and wind velocity observed in close proximity to the building. These data are being analyzed and a paper is being prepared for presentation to the Society. This study and the resulting report should add much to knowledge of the variation in the daily heating load with occupancy and outside weather conditions for a typical university building.

Heat Requirements—Agricultural and Mechanical College of Texas: Plans have been perfected through the committee and the Laboratory, in cooperation with Professor F. E. Giesecke, for a study of the heat requirements of one of the buildings at the Agricultural and Mechanical College of Texas. The active collection of the data in this study was started during the Fall and will be continued throughout the present heating season.

The building under test is heated with forced circulation hot water. Recording and integrating water flow meters located in the supply to, and return from, the building, together with recording thermometers, will give an accurate record of the heat delivered to the building. Recording thermometers located throughout the building will give the air temperatures maintained, which taken together with the construction characteristics of the building and the outside temperature, wind velocity and solar radiation will allow a close correlation between our available knowledge of heat transfer and heat capacity of the walls and the actual heat loss under normal building operation and weather conditions.

Heat Requirements—Grant Building, Pittsburgh, Pa.: The Research Laboratory has made a study of the hourly heat load required to maintain uniform temperatures in eight offices, having three exposures and on three different floors of the Grant Building, during the last half of the 1933-34 heating season. This study has already resulted in the paper, Wind Velocities Near

a Building and Their Effect on Heat Loss. Additional data collected in this study are being analyzed and will be presented to the Society at a later date. This study should result in a correlation between the actual heat loss from the several rooms studied and the simultaneously existing temperature and wind velocity, both as reported by the Weather Bureau for the city and as actually observed a short distance outside of each individual room window.

Comparative Heat Loss from Insulated and Non-Insulated Buildings: The committee was recently supplied a mass of tabulated data collected for it, giving the heat requirements in insulated and non-insulated, electrically heated buildings in Mason City, at the Grand Coulee Dam Site, State of Washington. These data will be analyzed with a view of presenting a paper on the subject to the Society.

Degree Day: A further analysis of the degree-day method of estimating heating requirements and its application to various types of buildings and methods of heating is being made.

Study of Heat Flow Through Roofs and Walls of Buildings as Affected by Heat Capacity and Solar Radiation: The Research Laboratory has from time to time studied heat flow through walls with the Nicholls Heat Flow Meter under various natural weather conditions. It has also supplied data on cyclic flow of heat through three typical roof decks resulting from the diurnal change in weather, including solar radiation. It is felt that an additional study of this subject should be made with a view of making the findings more easily applied in the estimation of heating and cooling requirements. This continued study is being considered by the committee.

Study of Conductivity of Concrete and Heat Transfer Coefficients for Various Wall Constructions Containing Concrete: Through cooperation between the Research Laboratory, the University of Minnesota and the *Portland Cement Association,* a study is being carried on by Prof. F. B. Rowley at the University of Minnesota, on the various factors affecting conductivity and heat transfer coefficients for walls containing concrete. The work has been in progress for a year, during which time 30 different types of walls were constructed and tested to determine their thermal properties. These walls contain different types of aggregate such as sand, gravel, crushed limestone, cinders and haydite. Insulating materials have been placed in the cells of the hollow blocks of some of the walls, and in other cases insulating materials have been used as a sheet of uniform thickness over the full area of the wall. A paper[9] covering the results thus far obtained will be presented to the Annual Meeting. A further program has been formulated, including the construction of an additional 15 walls, which will show the effect of different applications of insulating materials. A report covering this part of the work will be published next spring.

12. HEAT TRANSFER OF FINNED TUBES WITH FORCED AIR CIRCULATION

F. B. Rowley, *Chairman*

S. H. Downs	R. H. Norris
H. F. Hutzel	W. E. Stark
E. J. Lindseth	G. L. Tuve

The committee has continued to give consideration to a number of phases of this complicated problem, including the effect of:

(1) Reversing the direction of heat flow; that is, cooling air with same number of degrees temperature difference between the water flowing through the coil and the air, and with the same velocity of water through the coil and the same velocity of air through the heater.

(2) Investigation of the effect of the velocity of the water flowing in the tube on the surface coefficient of heat transfer from water to tube, or vice-versa.

(3) A study of heat transfer in the dehumidification of air by direct expansion of Freon in the coils.

A laboratory study is being made by Prof. G. L. Tuve at Case School of Applied Science. Following the publication of the first report on the subject in 1934, 250 one-hour tests have been made and the results have been correlated with data published by other investigators and with the performance tables published by manufacturers of finned tubing. The study so far indicates that while there is available fair knowledge of the laws governing heat transfer to or from finned tubing, the data available to engineers are in some respects inconsistent. More research is necessary, especially in the field of dehumidification, in order to establish a satisfactory basis for uniform methods of rating these units. It is suggested that the Society establish a simple and uniform method for testing any given design of extended surface unit, and to specify certain features in the developing of complete performance tables from such tests. A report[8] giving the results of the study to date will be presented to the Annual Meeting. This report includes a suggested method of establishing ratings.

13. MINIMUM TEMPERATURE AND METHOD OF INTRODUCTION OF COOLING AIR IN CLASSROOMS

Perry West, *Chairman*

J. D. Cassell	A. J. Nesbitt
S. R. Lewis	G. E. Otis
J. R. McColl	C.-E. A. Winslow

The work of this committee as originally outlined was carried out by the Laboratory in schools in the Pittsburgh district. The study resulted in three papers[2,4,6] presented at the Semi-Annual Meeting. While these papers were not entirely conclusive as regards all the phases of the subjects studied, they have served to clarify our understanding of the subject, and no further investigations have been planned by the committee.

14. REFRIGERATION IN RELATION TO AIR TREATMENT

M. K. Fahnestock, *Chairman*

E. A. Brandt	K. W. Miller
John Everetts, Jr.	E. B. Newill
E. D. Harrington	F. G. Sedgwick
E. D. Milener	J. H. Walker

The studies carried on under the committee in summer cooling in the Research Residence at the University of Illinois were continued through the summer of 1935, using city supply water available at a temperature of 58 F as the cooling medium. With the exception of the cooling coils and the air circulating fan the duct system was the same as in the previous studies made during the summers of 1932, 1933 and 1934. Due to the unusually cool summer it was possible to supplement the artificial cooling required during the daytime with cooling with outdoor air at night for practically the entire season. The amount of cooling was controlled by an *on* and *off* motor valve located in the water supply line to the cooling coils. A common type of thermostat operated the motor valve to maintain a constant temperature of approximately 80 F in the house. For a few tests, when an attempt was made to maintain a constant effective temperature in the house, the thermostat was supplanted with manual operation. Over the entire periods requiring cooling, the air recirculating fan was operated continuously and outdoor air equivalent to approximately one air change per hour was brought into the house for the purpose of ventilation.

The results of the summer's work using the city supply water with a temperature of 58 F indicated:

(1) That the amount of cooling coil surface required added considerable air resistance to the recirculating system, necessitating the installation of a materially larger recirculating fan than that required for heating.

(2) That a dry-bulb temperature of 80 F could be satisfactorily maintained with the water cooling coils.

(3) That although an appreciable amount of dehumidification was obtained it was not sufficient to reduce the relative humidity in the house below 63 per cent and the resulting air conditions could not be regarded as entirely satisfactory.

The work will be continued during the summer of 1936 using water at two different temperatures below 58 F. The mechanical refrigerating equipment, including a condensing unit and water cooler, for cooling water to any desired temperature, is installed in the Research Residence and ready to operate.

The *National Warm Air Heating and Air Conditioning Asso-*

ciation and a number of manufacturers of air conditioning apparatus cooperated in these studies. A paper will be presented at the next Semi-Annual Meeting.

15. SOUND IN RELATION TO HEATING AND VENTILATION

V. O. Knudsen, *Chairman*

Carl Ashley	J. S. Parkinson
C. A. Booth	C. H. Randolph
F. C. McIntosh	J. P. Reis
R. F. Norris	G. T. Stanton

The committee continued its study of various phases of the subject throughout the year. A meeting was held in New York on December 9, attended by five members of the committee and others. Consideration was given to the problem of setting up a suitable procedure for measuring the noise of equipment in the factory or laboratory. It was felt that such measurements should be so made that the results would enable the manufacturer to predict what level his equipment would set up in actual installations. Among the factors discussed were the type of room to be used, the type of noise meter, the direction of the microphone and its distance from the unit, etc.

Consideration was given by the committee to a table of noise levels representing the weighted average of figures obtained from all available sources on this subject. This table is given:

	Loudness Level in Decibels to be Anticipated[a]		
Location	*Min.*	*Representative*	*Max.*
Room Locations			
Sound Film Studios	10	14	20
Radio Broadcasting Studios	10	14	20
Planetarium	15	20	25
Residence Apartments, etc.	25	35	40
Theaters—Legitimate	25	30	35
Theaters—Motion Picture	30	35	40
Auditoriums, Concert Halls, etc.	25	30	40
Churches	30	35	40
Executive Offices—Treated Private Offices	25	33	40
Private Offices—Untreated	40	45	50
General Offices	50	55	60
Hospitals	20	50	70
Class Rooms	30	40	50
Libraries, Museums, Art Galleries	30	40	45
Public Buildings—Court Houses, Post Offices, etc.	45	55	60
Small Stores	40	50	60
Upper Floors Department Stores	40	50	55
Stores—General—including Main Floor of Department Stores	50	60	70
Hotel Dining Rooms	40	50	60
Restaurants and Cafeterias	55	65	75
Banking Rooms	50	55	60
Factories	60	70	80
Office Machine Rooms	60	70	80
Vehicular Noise			
Railroad Coach	60[b]	70	80
Pullman Car	55[b]	65	75
Automobile	50	65	80
Vehicular Tunnel	75	85	95
Airplane	80	90	100

[a] It is assumed that if equipment noise alone is not greater than these levels of background noise at any frequency band, results will be commercially satisfactory. When both are heard together, an increase in total level of 3 db can be anticipated.

[b] For train standing in station a level of about 45 db is the maximum which can ordinarily be tolerated.

Consideration was also given to an acceptable improvement in the standard available data on sound in relation to heating and ventilation as contained in The Guide.

The committee agreed that there was need for more research on this subject than could be expected from commercial firms now interested. In particular, information is needed on the relation between factory or laboratory measurements on the total noise given off by a unit and the actual levels set up in installation. The simple theory on this point requires considerably more experimental vertification than is now available. Information is also to be desired on the effect of sound absorbent linings in different sizes and length of duct, and in particular on the effect of such linings in elbows and turns. This problem has been the subject of considerable research by several firms, but the information is by no means complete. It is the recommendation of the committee that the Committee on Research consider the desirability of conducting such studies at the Research Laboratory of the Society.

16. VENTILATION OF GARAGES AND BUS TERMINALS

E. K. Campbell, *Chairman*

S. H. Downs	F. H. Hecht
T. M. Dugan	H. L. Moore
E. C. Evans	A. H. Sluss

The committe continued to give consideration during the year to various problems in connection with garage ventilation. The Garage Ventilation Code, prepared by the committee, was presented to the Society for final consideration and was adopted. Consideration was given to a proposal made by persons interested in ozone for its use in garages in order to minimize the harmful effects of carbon monoxide on occupants. From all information available on the probable chemical reactions between carbon monoxide and ozone in the atmosphere, and the effect of carbon monoxide on persons, either with or without the presence of ozone, it is indicated rather conclusively that no benefit could be had from such application. However, in order not to be too arbitrary in the matter, the committee proposed a brief scientific study of the subject at the Research Laboratory in cooperation with the U. S. Bureau of Mines and the U. S. Public Health Service. This proposal has not been accepted by those promoting the idea.

Death of Ralph Collamore

Members of the Society and the many friends of Ralph Collamore will be saddened to learn of his death on November 22, 1935.

Mr. Collamore had long been associated with the heating and ventilating engineering profession. He was born February 2, 1875, at Toledo, Ohio, and he received his preparatory education in the city high and manual training schools. In 1897 he was given the degree of B. S. M. E. from the University of Michigan.

Beginning in September 1897 Mr. Collamore was associated with the firm of Field and Hinchman, Detroit, Mich., and their successors Field, Hinchman and Smith. He became secretary of the latter firm and retained this position with Smith, Hinchman and Grylls, well-known architects and engineers.

Mr. Collamore became a Member of the American Society of Heating and Ventilating Engineers in 1904 and he served as a member of the Society's Board of Governors in 1913.

The Officers and Council of the Society wish to express their sincere sorrow for the loss which has been sustained.

Watt Bicentenary Observed

Honor was paid to James Watt, inventor of the Watt steam engine, when the 200th anniversary of his birth was observed in the United States, January 19-21, 1936.

Special programs were arranged by Lehigh University, Franklin Institute of the State of Pennsylvania, the *American Society of Mechanical Engineers,* and the *Newcomen Society of England.*

On Sunday, January 19, an international broadcast from the Science Museum, South Kensington, London, England, was heard at Franklin Institute, Philadelphia, Pa., and models of Newcomen and Watt engines and other appropriate exhibits were on display.

Tribute to James Watt was paid on January 20 at Lehigh University, Bethlehem, Pa., when an interesting program was enjoyed. On January 21 an exhibition and demonstration of the Watt steam engine was given in the Hall of Prime Movers of Franklin Institute and a meeting of the *Newcomen Society of England* was held. A formal dinner at the Bellevue-Stratford Hotel, Philadelphia, Pa., with appropriate addresses, closed the celebration.

Chicago Skyline

42nd Annual Meeting

MEMBERS of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS are enthusiastic about the 42nd Annual Meeting held at the Palmer House, Chicago, Ill., January 27-30, 1936. All attendance records were broken with a total registration of 1265 members and guests who came from all parts of the United States and Canada.

A business meeting and three technical sessions, in the Red Lacquer Room, had an unusually large attendance, which was particularly gratifying to Pres. John Howatt and the Committee on Arrangements of Illinois Chapter.

Special attention was given to the entertainment of members, ladies, and guests and the plans made by the Illinois Chapter provided delightful diversion and were heartily enjoyed by all who attended.

Reception and registration began on Monday morning and a business meeting was devoted to annual reports and discussion of the Proposed Standard of Rating and Testing Air Conditioning Equipment. The results of the election of Officers and members of the Council for a three-year term were announced by R. H. Carpenter, chairman of the Tellers of Election.

On January 27 the Council had a luncheon and meeting at the Saddle and Sirloin Club, Stock Yards Inn, and then took part in the formal opening of the 4th International Heating and Ventilating Exposition held at the International Amphitheatre in conjunction with the A. S. H. V. E. Annual Meeting. Later members of the Council met for the transaction of Society business with every Council member in attendance.

An informal reception Monday evening featured Miss Alice Blue, pianist of Station WGN, who played in the Illinois Chapter Room at the Palmer House.

The first technical session opened on Tuesday morning, when J. H. Milliken, president of the Illinois Chapter and chairman of the Committee on Arrangements, greeted A. S. H. V. E. members and guests. President Howatt responded and a Welcome to Chicago was given by the Hon. Edw. J. Kelly, Mayor of the city. Three papers were presented on the subjects of Thermal Properties of Concrete Construction, Comparative Study of Combustion Results with Various Thermostats, and Fuel Saving Resulting from the Use of Storm Windows and Doors. A Get-Acquainted luncheon for members and guests was enjoyed in the Chicago Room and in the afternoon the Committee on Research, Chapter Officers, and the Nominating Committee held meetings.

The Past Presidents held their annual dinner Tuesday evening and initiated C. V. Haynes as a member of this august group. A House-Warming Party in the Red Lacquer Room provided entertainment by Norman Ross and his N. B. C. Amateurs, and dancing to music by the Broadcasters.

Wednesday morning's session was given over to the presentation of four technical papers on Performance of Fin-Tube Units for Air Heating, Cooling and Dehumidifying, Subjective Reactions of Human Beings to Certain Outdoor Atmospheric Conditions, Ventilation Requirements, and Airfoil Fan Characteristics. In the afternoon a joint meeting was held with the *National Warm Air Heating and Air Conditioning Association* at the Stevens Hotel. The A. S. H. V. E. was represented on the program by the presentation of a paper on Room Surface Temperature of Glass Windows.

This year the Annual Banquet and Dance, in the Grand Ballroom of the Palmer House, was attended by 710. It was an occasion of unusual note and included a broadcast by President Howatt over the N. B. C. blue network on the Armco program dedicated to Air Conditioning.

Honor was paid to Dr. Arthur Cutts Willard, president of the University of Illinois, past president of the A. S. H. V. E., research technical adviser and member of the Society, who received the F. Paul Anderson Medal. The presentation of the award to Dr. Willard was made by President Howatt, who in turn was honored by receiving the A. S. H. V. E. past president's emblem from S. R. Lewis. O. J. Prentice was toastmaster and Maj. John L. Griffith addressed the gathering on Competition in Athletics and in Business. Earlier in the evening beautiful vocal selections were rendered by the famous Old Heidelburg Octette and later Waddy Wadsworth and his band played for dancing.

In spite of the strenuous night before, a large number of members and guests were on hand early Thursday morning for the final session. On the program were papers presenting Comfort Standards for Summer Air Conditioning and Corrosion Studies in Steam Heating Systems. The installation of officers, resolutions, and other business took place before the 42nd Annual Meeting of the A. S. H. V. E. was adjourned.

A luncheon and organization meeting of the new Council followed, as well as a meeting of the Guide Publication Committee. On Thursday afternoon and Friday morning inspection trips were made to various manufacturing plants.

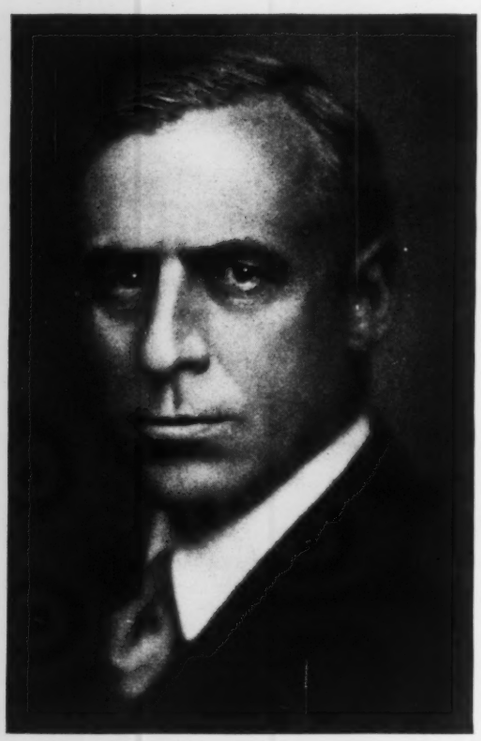
The ladies enjoyed the use of the Illinois Chapter Room and in addition to the evening events, they were entertained by a tea, a trip to the Chicago Art Institute, a luncheon and style show at Marshall Field & Co., a tour of a radio broadcasting station and a bridge party.

The Committee on Arrangements is to be congratulated on its plans and efforts which resulted in the successful operation of the largest meeting in the history of the A. S. H. V. E., the complete proceedings of which will appear in the March issue of the Journal.

A. S. H. V. E. Officers Elected in 1936

G. L. Larson
Madison, Wis.
President

D. S. Boyden
Boston, Mass.
First Vice-President



E. H. Gurney
Toronto, Can.
Second Vice-President

Alfred J. Offner
New York, N. Y.
Treasurer

Council Members Elected for Three-Year Term

R. C. Bolsinger
Norristown, Pa.

S. H. Downs
Kalamazoo, Mich.

W. L. Fleisher
New York, N. Y.

C. M. Humphreys
Pittsburgh, Pa.

Local Chapter Reports

Illinois

January 13, 1936. This occasion was Ladies' Night and a dinner meeting was held in the Louis XVI room of the Sherman Hotel, where twelve large tables were set with decorations and place cards. An issue of *Time* featuring Dr. A. H. Compton, who was the distinguished guest of honor, was at each place.

After dinner, Pres. J. H. Milliken called on Secy. L. S. Ries to introduce Dr. Compton, Professor of Physics at the University of Chicago, and Nobel Prize Winner of 1927, who was the speaker of the evening.

Dr. Compton gave an interesting and instructive discussion of Cosmic Rays illustrated with stereopticon slides in color. During the many expeditions which he has made with the cosmic ray meter involving a distance of more than 50,000 miles, he has visited various parts of the United States, the top of mountains in Hawaii, valleys and mountain tops of New Zealand, the highest peak in Australia, Peru, Mexico City and northern Canada in the Hudson's Bay near the north magnetic pole.

Dr. Compton stated that as a result of study of cosmic rays the positive electron was discovered, and he expressed the opinion that by means of cosmic rays human beings would be able to develop another type of measuring stick to gage their history.

At the close of the talk members of the Illinois Chapter gave Dr. and Mrs. Compton a hearty ovation.

A motion was made by J. J. Hayes that recommendation be made to the Chapter's Nominating Committee for the renomination of the officers, who are now serving, for reelection. This motion was seconded and passed.

President Milliken spoke of the 42nd Annual Meeting of the Society to be held in Chicago the week of January 27 and he introduced the committee chairmen, who gave short talks. President John Howatt of the A. S. H. V. E. was presented and gave an outline of the work which had been done by the various committees.

The remainder of the evening was devoted to social activities and there was a total attendance of 104, of whom 40 were wives of the chapter members.

Washington, D. C.

January 8, 1936. A successful meeting of the Washington, D. C., Chapter was held at the Shoreham Hotel. Fifty-three were present at dinner at 6:30 p. m. and among the distinguished guests were: Major General C. R. Reynolds, Surgeon General of the United States Army, Dr. Wm. Gerry Morgan, Dean of the School of Medicine, Georgetown University, and W. E. Reynolds, Assistant Director of the Procurement Division of the Treasury Department.

After dinner the members and guests adjourned to the ballroom for the technical session when approximately 400 people were present.

Pres. W. A. Danielson introduced L. Sherman, New York, N. Y., who gave a preliminary talk and demonstration of water treatment for steam boilers, using a glass model, and showing the results obtained from clean and unclean boilers.

At 8:35 p. m. President Danielson called the meeting to order and read a letter from Pres. John Howatt of Chicago, Ill., in regard to the A. S. H. V. E. Annual Meeting. In addition the members were asked to give President Danielson suggestions regarding subjects which they felt should be studied by the Committee on Research of the A. S. H. V. E. during the coming year.

Dr. C. A. Mills, Professor of Experimental Medicine at the University of Cincinnati, was introduced by President Danielson as the speaker of the evening. Dr. Mills gave a very interesting address on the Physiologic and Medical Aspects of Air Conditioning and amplified his talk with slides. Dr. Mills has made intensive and original scientific research in many countries on the effect of varous climates on various races and the physiological and beneficial effects of air conditioning on the human being.

Dr. Mills' address was followed by an interesting discussion of its subject matter by many of the members and guests.

Secy. M. D. Kiczales reports that the meeting adjourned at 10:40 p. m.

Manitoba

The following A. S. H. V. E. members have the honor of being Charter Members of the recently organized Manitoba Chapter: James Aitken, E. J. Argue, H. R. Eade, E. Fitz Munn, William Glass, B. G. Jones, R. L. Kent, D. F. Michie, E. R. Miller, J. B. Steele, E. T. Summers, Frank Thompson, C. H. Turland, H. D. Watson, and James Yates.

Officers serving the Chapter are J. B. Steele as President and C. H. Turland as Secretary.

Massachusetts

December 19, 1935. A meeting of the Massachusetts Chapter was held at Massachusetts Institute of Technology and many of the members enjoyed dinner at the Walker Memorial prior to the meeting.

Secy. G. B. Gerrish reports that a motion was passed recording the Chapter's approval of the exchange service plan with the *American Society of Refrigerating Engineers,* which had recently been announced.

The speaker of the evening was Prof. J. A. Holt, Department of Thermodynamics, M. I. T., who discussed the Steam Jet Refrigeration Cycle. With the aid of slides, Professor Holt described the design of several types of machines in commercial use. His explanation of the fundamental principles involved made clear the underlying reasons for changes and developments, which the speaker traced through to the most modern equipment.

Professor Holt showed that with these developments a marked improvement in economy has resulted, so that the cost of operating steam jet machines compares favorably with mechanical refrigeration, although consideration must be given to the sources and cost of providing the increased cooling facilities required.

After Professor Holt had answered the questions of several of the members and a general discussion had been enjoyed, the meeting was closed.

Minnesota

December 16, 1935. The Minnesota Chapter held its meeting at the Minnesota Union, University of Minnesota. Dinner was served at 6:30 after which the meeting was called to order by Pres. C. E. Gausman. The minutes of the two previous meetings were read and approved.

Albert Buenger discussed briefly the Society's Annual Meeting in Chicago and also outlined the proposed plan between the *A.S.R.E.* and A.S.H.V.E. for holding joint meetings and exchanging publications. A. J. Huch suggested that an Arrangements Committee be appointed to make plans for Minnesota Chapter members attending the Annual Meeting.

Prof. A. B. Algren, who had kindly consented to present the paper Comfort Standards for Summer Air Conditioning, was introduced. The clear, concise manner in which the paper was given, together with the slides of the various charts and graphs appearing in the original paper, made this a very interesting meeting.

Written discussions were presented by the following members: J. R. Roberts, R. C. Jordan, H. C. Betts, and J. B. Spencer.

A lively oral discussion by M. H. Bjerken, C. R. Barnum, C. E. Lund, A. J. Huch, C. E. Gausman, K. A. Powell, G. D. Kingsland, F. B. Rowley, and A. B. Algren followed, giving

evidence of the fact that this paper had aroused a great deal of interest among the members.

Mr. Buenger expressed sincere gratification at this reaction. He explained that early in the Spring, Pres. John Howatt had been desirous of finding a subject that could be given to the Chapters for study and consideration. There is no question that Comfort Standards for Summer Air Conditioning has been brought closer to the entire membership because of this plan. It is hoped that, in the future, other papers, especially those of as wide general interest, can be handled in a similar manner.

Thirty-eight members were present according to the report of Secy. R. E. Backstrom.

Ontario

January 6, 1936. Forty-eight members and guests were present at the regular meeting of the Ontario Chapter at the Royal York Hotel which was preceded by dinner at 6:30 p. m.

Pres. M. W. Shears called upon Secy. H. R. Roth to read the minutes of the previous meeting which were accepted as read.

President Shears urged that as many members as possible attend the 42nd Annual Meeting of the Society in Chicago during the week of January 27.

E. R. Gauley introduced the principal speaker of the evening, Prof. E. A. Allcut, of the University of Toronto, who spoke on Heat Transmission Through Materials. Following Professor Allcut's interesting illustrated talk the members entered into a discussion of the subject.

W. P. Boddington moved that a vote of thanks be given the speaker on behalf of the Chapter before the meeting adjourned.

Philadelphia

January 9, 1936. Members and guests of the Philadelphia Chapter held their annual January Get-together at the Hudson Recreation Centre.

Pres. J. H. Hucker presided and introduced R. F. Hunger, Chairman of the Membership Committee, who presented the awards for the membership campaign. L. C. Davidson received a golf iron, and M. G. Kershaw was the recipient of a pen and desk stand.

A. E. Kriebel, Chairman of the Year Book Committee, spoke on the importance of securing advertisements in order that the book might be successfully published.

President Hucker urged members to attend the Society's Annual Meeting in Chicago and announced that the Philadelphia Chapter had again been appointed to act as hosts for the A. S. H. V. E. at the 1936 Semi-Annual Meeting to be held at Buck Hill Falls, Pa.

There being no further business, the meeting was adjourned to allow the festivities to begin.

Secy. H. H. Erickson reports that a delicious buffet supper was served with refreshments and, after partaking of this, members and guests indulged in the rather strenuous exercise of bowling. The evening was a grand success and every one present enjoyed himself. It was a real pleasure to listen to the old-timers alibi themselves by advising their opponents that they hadn't bowled for 20 years or more. But they proved that they could "take it," despite the fact that liniment sales increased in the community as a result.

The party ended at 10:30 to allow the participants to rest up for the next day's battle with life and business. The Entertainment Committee, of which S. E. Plewes was chairman, deserved and received the plaudits of the chapter.

Pittsburgh

January 13, 1936. The regular meeting of the Pittsburgh Chapter was called to order by Pres. R. J. J. Tennant in the auditorium of the U. S. Bureau of Mines. Fifty-one members and guests were present and Secy. T. F. Rockwell read the minutes of the December meeting.

Treas. J. F. Collins, Jr. reported that 1936 chapter dues were payable and that bills would be mailed during the coming week.

Plans for the February meeting were outlined and it was announced by M. L. Carr, Chairman of the Program Committee, that R. A. Miller would speak on New Types of Architectural Glass and Their Heat Transfer Properties.

A report on action taken regarding the 1937 Annual Meeting of the Society was given by President Tennant.

Prof. C. M. Humphreys read the January letter of Pres. John Howatt of the A.S.H.V.E., extending an invitation to all members to attend the Society's Annual Meeting and Heating and Ventilating Exposition in Chicago during the week of January 27.

In accordance with the wishes of the Chapter expressed at the November meeting, President Tennant appointed the following committee to study the problem of Air Pollution: F. H. Hecht, *Chairman*, T. G. Estep, and E. S. Tower.

Professor Estep then briefly described a research project now under way at Carnegie Institute of Technology to make a quantitative determination of the solids discharged by a domestic chimney. It was reported that during the first of the investigation the performance of an underfeed domestic stoker burning bituminous coal was being studied.

President Tennant appointed the following standing committees for 1936:

Program Committee—M. L. Carr, *Chairman*, W. H. Osterle, W. W. Stevenson, H. L. Moore, and F. C. Houghten.

Membership Committee—F. C. McIntosh, *Chairman*, E. C. Smyers, P. C. Strauch, Roy Brauer, and P. A. Edwards.

Attendance and Social Committee—R. B. Stanger, *Chairman*, T. M. Dugan, L. S. Maehling, Peter O'Neill, and E. H. Riesmeyer, Jr.

Committee on Code for Installation of Air Conditioning—G. S. McEllroy, *Chairman*, P. A. Edwards, and G. G. Waters.

E. B. Svenson was introduced by Mr. Collins and spoke on the Use of Aluminum Foil as a Heat Insulation Material. He first reviewed briefly early work in the use of polished metal surfaces for the purpose of reducing heat transfer, and then told the story of the development of the idea of crumpled foil.

Mr. Svenson illustrated his talk with motion picture films, which showed methods of installing foil insulation on steam piping, turbines, tanks, locomotives, railroad cars, trucks, buses, and in houses. The speaker also explained the details of installation and answered questions raised by various persons in the audience.

According to the report of Secretary Rockwell, the members and guests gave every indication that they enjoyed Mr. Svenson's talk and the meeting adjourned at 9:50 p.m.

December 16, 1935. The meeting was called to order by Pres. L. B. Pittock in the auditorium of the U. S. Bureau of Mines with 34 members and guests present. The minutes of the previous meeting were approved as read by Secy. T. F. Rockwell.

E. C. Smyers, Chairman of the Membership Committee, reported one new member and one advancement in membership grade for the month of December.

In the absence of H. A. Beighel, Secretary Rockwell read the annual financial report.

The correlation of weather data was the next subject of discussion, and in a progress report Chairman F. A. Gunther drew attention to the fact that examination of the operating records of several buildings revealed that during the beginning and end of the heating season degree days did not serve as an accurate index of the fuel or steam consumption. Mr. Gunther also asked Chapter members to submit their suggestions on several questions to the Committee.

It was moved by H. L. Moore, seconded by E. C. Evans, and passed that the following officers be elected unanimously:

President—R. J. J. Tennant.
Vice President—M. L. Carr.
Secretary—T. F. Rockwell.
Treasurer—J. F. S. Collins, Jr.
Board of Governors—L. B. Pittock, Percy Nicholls, E. S. Tower.

The retiring president, L. B. Pittock, thanked the members for their cooperation and aid during his administration and mentioned

his hope that the newly elected president would continue the study of the degree day problem.

In a brief introduction President Tennant outlined his plans for the new year and expressed his wish that improved conditions would permit the resumption of greater social activities for Chapter members.

Pres. John Howatt's letter for December was read by P. A. Edwards and it was suggested that the Pittsburgh Chapter take steps to formulate a code of air conditioning standards suitable for the community.

After a brief discussion it was moved, seconded and passed that the Pittsburgh Chapter issue a written invitation to the National Council of the A. S. H. V. E. and to other chapter officers to hold the Society's Annual Meeting 1937 in the City of Pittsburgh.

Mr. Pittock called attention to the Annual Meeting of the A. S. H. V. E. and the exposition in Chicago in January and it was voted that the chapter president be the authorized representative to the Annual Meeting.

President Tennant introduced F. C. Houghten, Director of the A. S. H. V. E. Research Laboratory, who spoke on the recent laboratory paper, Comfort Standards for Summer Air Conditioning. Mr. Houghten showed the results of his tests by slides and in conclusion he invited criticism of the paper and explained that the Laboratory planned to continue the study on a larger scale including both southern and northern cities.

In a written discussion Arthur McGonagle expressed the desirability of definite standards for inside conditions from the viewpoint of the designing engineer. A general discussion followed in which a large number of members and guests took part.

Western New York

December 17, 1935. The annual Christmas party of the Western New York chapter was held at the University Club, Buffalo, and Pres. W. E. Voisinet presided over a short business meeting. Pres. John Howatt's message to A. S. H. V. E. chapters concerning the necessity of establishing standards for air conditioning in every large community was read, and it was announced that the Chapter's Committee on Air Conditioning Standards would begin active work at an early date.

C. A. Gifford, Chairman of the Publicity Committee, read many telegrams addressed to various chapter members from anonymous persons and the audience enjoyed the comments on their activities.

Following adjournment of the business meeting, the members were on their own to enjoy the facilities of the club, which were provided through the courtesy of D. J. Mahoney, a Past President of the Chapter. The bowlers started a mass attack on the maples while others chose to play cards. The evening was concluded with a fine buffet lunch and, according to the report of Secy. J. J. Landers, it was thoroughly enjoyed by the 45 members and guests in attendance.

Wisconsin

December 16, 1936. At the regular meeting of the Wisconsin Chapter Pres. John Howatt's letter on Air Pollution was read and discussed. S. G. Swisher, Jr., was appointed to investigate causes of air pollution in Milwaukee and recommend methods for its abatement.

E. A. Jones was appointed as Chapter representative on the A. S. H. V. E. Nominating Committee with Ernest Szekely as alternate. Other appointments were J. H. Volk as delegate to the Annual Meeting in Chicago with J. S. Jung as alternate.

A very interesting discussion on the Chicago Air Conditioning Standards and the Annual Meeting paper, Comfort Standards for Summer Air Conditioning, prepared by the A. S. H. V. E. Research Laboratory, was led by Mr. Szekely.

Secy. R. G. Koch reports that the Wisconsin Chapter feels the need for a similar code, although it is realized that much more data and information are needed to prepare one which would be satisfactory. Mr. Szekely was appointed by the Chapter to initiate a movement for obtaining such a code for the Milwaukee territory.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 36 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by February 15, 1936, these candidates will be balloted upon by the council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
AIKMAN, J. M., Air Cond., Htg. and Vtg. Engr., Webster Engrg. Co., Minneapolis, Minn.	S. R. Lewis A. B. Martin	W. F. Uhl E. V. Hill
ANDRESEN, G. C., Student, Yale University, New Haven, Conn.	L. E. Seeley L. A. Teasdale	L. C. Lichty (*Non-Member*) S. W. Dudley (*Non-Member*)
ANDERSON, G. A. M., Sr. Mech. Engr., University of Minnesota, Minneapolis, Minn.	F. B. Rowley A. B. Algren	J. V. Martenis B. J. Robertson (*A.S.M.E.*)

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BARNEY, W. E., Dist. Mgr., Hydraulic Press Brick Co., South Park, Ohio.	R. L. Smith (*Non-Member*) Wm. Andes	F. A. Kitchen G. W. Beyerle (*S.A.E.*)
BOYLE, J. R., Asst. Chief Engr., Westerlin & Campbell Co., Chicago, Ill.	R. E. Hattis S. I. Rottmayer	J. J. Hayes J. H. Milliken
CARTER, A. W., Htg. Engr., Monarch Brass Mfg. Co., Ltd., Toronto, Ont., Can.	W. R. Blackhall A. S. Leitch	H. H. Angus H. R. Roth
CLARKE, J. G., Sales Engr., Frigidaire Corp., Dayton, Ohio.	L. E. Smith C. E. Lewis	M. J. Stevenson H. B. Hull
COVER, R. R., Repr., Ferro-Nil Corp., Washington, D. C.	J. E. Ware, Jr. (*Non-Member*) R. M. Palmer (*Non-Member*)	J. E. Bell (*Non-Member*) J. C. Torket (*Non-Member*)
CURTIS, MAYES, Student, Oklahoma University, Oklahoma City, Okla.	E. F. Dawson W. H. Carson (*Non-Member*)	P. O. Tauson H. V. Beck (*Non-Member*)
DEAN, M. H., Student, Princeton University, Princeton, N. J.	H. M. Rudio C. A. Weiss	C. A. Flarsheim F. J. Dean, Jr.
DRAKE, G. M., Vice-Pres., Geo. H. Drake, Inc., Buffalo, N. Y.	J. J. Yager L. A. Harding	M. S. Jackson W. E. Voisinet
EDWARDS, A. W., Dist. Mgr., The Trane Co., Cincinnati, Ohio.	W. R. Stevens H. A. Pillen	G. B. Houliston K. A. Wright
GODDARD, W. F., Repr., American Radiator Co., Washington, D. C.	W. A. Danielson M. D. Kiczales	W. E. Kingswell T. H. Urdahl
HAWK, J. K., Engr., Hudson Air Cond. Corp., Washington, D. C.	F. H. Faust D. W. McLenegan	Elliott Harrington P. S. Lyon
GOULD, H. E., Sales Engr., Natkin & Co., Kansas City, Mo.	Emil Haas, Jr. Sidney Pines	B. Natkin Carl Clegg
HUNTER, L. N., Mgr. Research Dept., National Radiator Corp., Johnstown, Pa.	T. A. Novotney E. N. McDonnell	R. E. Moore B. E. Shaw
KARAKASH, T. J., Equipment Engr., Ford Motor Co., Istanbul, Turkey.	L. A. Scipio (*Non-Member*) E. S. Sheiry (*A.S.C.E.*)	A. G. Sarafoglou (*A.S.C.E.*) H. A. Walsdorf (*Non-Member*)
KARCHMER, J. H., Mgr. & Partner, The Karchmer Co., Springfield, Mo.	L. J. McAdams (*Non-Member*) C. H. Dunlap (*Non-Member*)	A. J. Lindsay (*Non-Member*) J. E. Manahan
LAUER, R. F., Sales Engr., York Ice Machinery Corp., York, Pa.	G. E. Tuckerman I. C. Baker	J. R. Hertzler L. J. Du Bois
LLOYD, E. H., Sales Engr., Washington Gas Light Co., Washington, D. C.	L. Ourusoff E. V. Fineran	T. H. Urdahl W. E. Kingswell
MCELHANEY, G. W., Air Cond. Engr., Pennsylvania Power Co., New Castle, Pa.	J. J. LaSalvia H. N. Boucherle	Chas. Sonneborn M. J. Stevenson
MEINHOLTZ, H. W., Br. Mgr., York Ice Machinery Corp., Oklahoma City, Okla.	S. L. Rolland Louin Tiller	E. S. Constant E. W. Gray
MORSE, L. S., Jr., Air Cond. Engr., York Ice Machinery Corp., York, Pa.	H. G. Chapin J. R. Hertzler	W. E. Zieber S. E. Lauer
PARSONS, L. D., Jr., Student, Purdue University, West Lafayette, Ind.	W. T. Miller (*Non-Member*) G. A. Young (*A.S.M.E.*)	A. A. Potter (*A.S.M.E.*) J. D. Hoffman
PELLMOUNTER, THOMAS, Dist. Sales Mgr., Century Elec. Co., Kansas City, Mo.	E. K. Campbell Carl Clegg	E. K. Campbell, Jr. L. A. Stephenson
RAMSAY, J. W., Salesman, King & Shepherd, New York, N. Y.	E. N. McDonnell W. G. Boales	R. F. Connell J. F. McIntire
ROBB, J. E., Dist. Mgr., Minneapolis-Honeywell Reg. Co., Kansas City, Mo.	David Caleb Carl Clegg	W. E. Gillham G. L. Bliss
ROBERTS, H. P., Asst. Engr., Roberts-Hamilton Co., Minneapolis, Minn.	M. H. Bjerken F. H. Schernbeck	G. A. Dahlstrom A. J. Huch
ROBINSON, A. S., Vent. & Htg. Engr., E. I. DuPont de Nemours Co., Wilmington, Dela.	M. G. Kershaw L. C. Davidson	R. F. Hunger F. D. Mensing

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
SALTER, E. H., Engr., Electrical Testing Labs., New York, N. Y.	F. M. Farmer (*Non-Member*) Gordon Thompson (*Non-Member*)	J. B. Whitehead (*Non-Member*) E. D. Doyle (*Non-Member*)
SEIDEL, G. E., Student, University of Minnesota, Minneapolis, Minn.	F. B. Rowley A. B. Algren	J. V. Martenis N. D. Adams
SMITH, R. J., Mgr., Smith & Elston, Timmins, Ont., Can.	E. H. Gurney G. T. Wilson	L. C. Blackhall D. I. Paul
STOCK, C. S., Dist. Repr., The Herman Nelson Corp., Moline, Ill.	H. W. Nelson R. H. Nelson	G. E. Otis E. H. Beling
TOROK, ELMER, Supt. of Power, North American Rayon Corp., Elizabethton, Tenn.	W. B. Hodge C. H. B. Hotchkiss	A. F. Karlson P. A. McKittrick
TRAMBAUER, C. W., Sales Engr., Hoffman Specialty Co., New York, N. Y.	J. K. Peacock M. C. Gillett	N. P. Fenner C. W. Stewart
VERVOORT, E. L., Student, University of Vermont, Burlington, Vt.	G. F. Eckhard (*Non-Member*) W. T. Fulton (*Non-Member*)	E. L. Sussdorff (*A.S.M.E.*) M. H. Aldrich (*Non-Member*)
WHITTINGTON, J. A., Utilization Testing Engr., The Peoples Gas Light & Coke Co., Chicago, Ill.	J. E. McClellan E. T. Murphy	J. H. O'Brien J. H. Milliken

Candidates Elected

In past issues of the JOURNAL of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Committee on Admission and Advancement and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. B-III, Sec. 8, of the By-Laws, the following list of candidates elected:

MEMBERS

BARNES, HERBERT, Plbg. & Htg. Contractor, Hamilton, Ont., Can.

BLUMENTHAL, M. I., Engrg. Instructor, National Schools, Los Angeles, Calif.

BOALES, W. G., Mfrs. Agent, Detroit, Mich. (*Advancement.*)

CASSELL, W. L., Consulting Engr., Kansas City, Mo.

CHAPMAN W. A., Jr., Dist. Engr. Frigidaire Corp., St. Louis, Mo.

DODGE, H. A., Elec. Engr., S. H. Kress & Co., New York, N. Y.

FAUST, F. H., Engr., General Electric Co., Bloomfield, N. J. (*Advancement.*)

GRAY, E. W., Br. Mgr., The Trane Co., Cleveland, Ohio.

HARRIS, J. G., Mgr. Air Cond. Dept., Frigidaire Corp., Cleveland, Ohio.

HUDEPOHL, L. F., Pres., T. J. Conner, Inc., Cincinnati, Ohio.

KENT, R. L., Dist. Mgr., Trane Co. of Canada, Ltd., Winnipeg, Man., Can.

KESSLER, JACOB, Pres., Jacler Heating Co., Inc., New York, N. Y.

MACMILLAN, A. R., Air Cond. Div., Frigidaire Corp., Dayton, Ohio.

MCLOUTH, B. F., Chief Engr., Heater Div., Dail Steel Products Co., Lansing, Mich. (*Advancement.*)

MORSE, R. D., Br. Mgr., American Blower Corp., Seattle, Wash.

ROOT, E. B., Htg. Engr. Detroit Safety Furnace Pipe Co. Birmingham, Mich.

STEWART, D. J., Mgr., Elec. Div., Barber-Colman Co., Rockford, Ill. (*Advancement.*)

TUXHORN, D. B., Htg. Engr., L. P. Steuart & Bro., Inc., Washington, D. C.

WILLIAMS, C. R., Draftsman, E. I. Du Pont de Nemours Co., Wilmington, Dela.

ASSOCIATES

BROOME, J. H., Student, New York University, New York, N. Y.

CASE, R. H., Mfrs. Repr., Seattle, Wash.

DOBIE, T. K., Supt. of Bldg., London Life Insurance Co., London, Ont., Can.

ESKIN, S. G., Grad. Student, Mass. Inst. of Tech., Boston, Mass.

GREGG, S. H., Pres., Shellenberger-Gregg Co., Milwaukee, Wis.

MANNY, J. H., Vice-Pres.-Secy., Robinson Furnace Co., Chicago, Ill.

MONICK, F. R., Mgr., Cochran-Sargent Co., Sioux Falls, S. D.

RITT, C. F., Sales Promotion Mgr., Trane Co., Washington, D. C.

WALLACE, H. P., Jr., Sales Mgr., Crane Co., Minneapolis, Minn.

WHITE, W. R., Engr. Nebraska Power Co., Omaha, Nebr.

JUNIORS

ADSHEAD, BERNARD, Tech. Director, National Air Cond. & Humidifying Co., Ltd., Manchester, 3, England.

CORNISH, D. F., Consulting Engr., Dominion Heating Specialty Co., Toronto, Ont., Can.

DOME, A. G., Engr., Bryant Air Cond. Corp., Philadelphia, Pa.

GRAHAM, J. M., Sales Engr., B. F. Sturtevant Co., Hyde Park, Mass.

GREGG, S. L., Sales Engr., Potomac Elec. Power Co., Washington, D. C.

HAWKINSON, C. F., Engr., U. S. Air Cond. Corp., Minneapolis, Minn.

LOVING, W. H., Cadet Engr., Washington Gas Light Co., Washington, D. C.

NYE, L. B., Cadet Engr., Washington Gas Light Co., Washington, D. C.

SUDDERTH, LEO JR., Sales Engr., Johnson Service Co., Atlanta, Ga.

STUDENTS

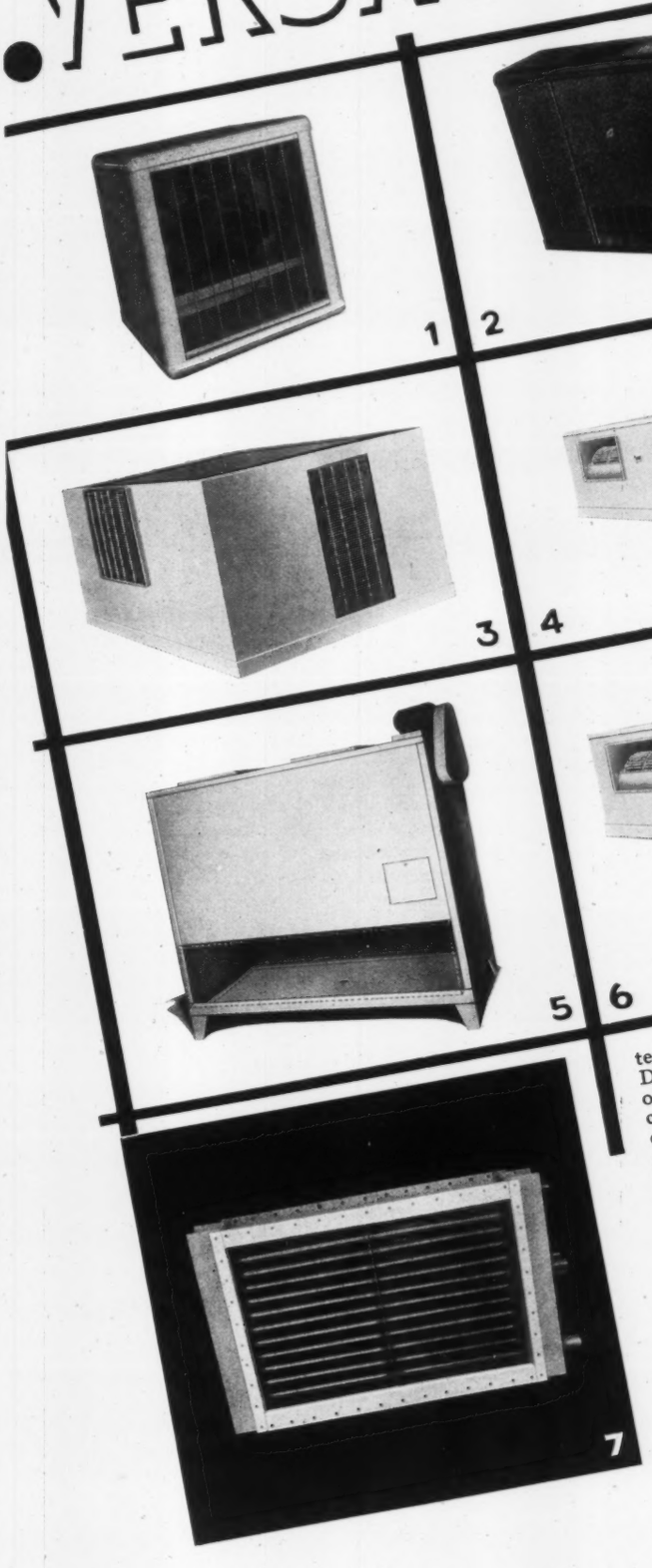
COOPER, T. E., Student, University of Minn., Minneapolis, Minn.

MOSES, W. B., Jr., Student, Tulane University, New Orleans, La.

O'ROURKE, H. D., Jr., Student, Stevens Inst. of Tech., Hoboken, N. J.

WILLIAMS, G. S., Student, Yale University, New Haven, Conn.

VERSATILITY



Air Conditioning equipment must be flexible enough in arrangement and type to meet the requirements of every kind of building. The illustrations on this page show the basic TRANE Units which engineers everywhere are selecting for their Air Conditioning systems. 1—Propeller fan type, suspended unit; 2—Deluxe floor cabinet unit; 3—Single fan hotel and office unit; 4—Commercial unit, low and medium capacity, suspended type; 5—Commercial unit, large capacity, floor type. 6—Commercial unit, large capacity, suspended type 7—The TRANE Direct Expansion Coil; also available for water cooling installations.

Back of this complete line of conditioning equipment is a field performance and experience procured from hundreds of installations. There are no limitations to your air conditioning system design when you specify TRANE. We will be glad to send complete data for your files together with lists of installations in every type of building.

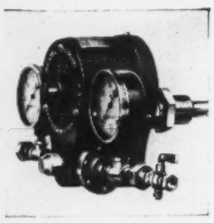
The TRANE Company La Crosse, Wisconsin

also

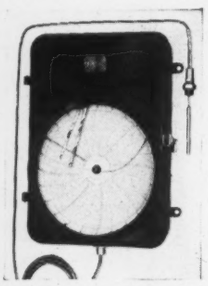
Trane Company of Canada, Ltd.
Toronto, Canada

PRECISION
Temperature Control
. . . . as you like it and as you need it

Full Floating Free Vane Air Operated Temperature Recorder Controller, Model 5240M. Class 2 vapor filled system. Single pen thermometer. Wall type.



Air Operated Temperature Controller, Expansion Stem System, Direct Acting, Series 250.



Direct - Set Mercury - Contact Electric Operated Temperature Recorder Controller, Model G 240L. For wall mounting.

Electric Operated Temperature Indicating Controller, Model 377B. With single or double adjustment contacts.

NO TWO control problems are alike. Consequently no one controller can be expected to serve best under all conditions.

Because of certain reasons which you can't overlook, or because of individual experiences and preferences, you may prefer one type of automatic temperature control. Other process conditions may require other types.

For this reason Bristol provides a complete line of equipment, so diversified in design, type, method of operation and applicability, that several solutions of a given problem often are available. This permits a selection assuring the highest efficiency.

Since in addition Bristol makes a complete line of automatic valves, Bristol is in the favorable position of being able to develop the complete control system as a balanced, correctly coordinated unit, and to assume undivided responsibility for its satisfactory performance.

Feel free to consult us.

THE BRISTOL COMPANY
WATERBURY, CONN.

Branch Offices in Principal Cities

Canada: The Bristol Company o Canada, Ltd., Toronto, Ontario.
England: Bristol's Instrument Co., Limited, London, S. E. 16

TRADE MARK
BRISTOL'S
REG. U. S. PAT. OFF.

PIONEERS IN PROCESS CONTROL SINCE 1889

Equipment Developments

For your convenience in obtaining more information about any of this equipment, see coupon on page 103. Add the new products and companies listed here to your Directory Section which you received in your January 1936 HEATING, PIPING AND AIR CONDITIONING and thus keep your records of sources of supply up to date throughout the year . . . Single asterisk (*) indicates equipment not listed in Directory Section; double asterisk (**) equipment and manufacturer not listed.

Three New Air Conditioning Instruments

No. 644—Among the new instruments displayed at the Fourth International Heating and Ventilating Exposition last month were three that attracted considerable interest—a new hand aspirated psychrometer, a "windowstat," and a new line of electric recorders for providing daily or weekly records of temperature and relative humidity at remote distances.

(a) The hand aspirated psychrometer has been developed to enable taking readings of wet and dry bulb temperatures in air conditioning survey work in occupied spaces without disturbing the tenants and without embarrassment to the engineer. Other advantages are that, as the instrument does not have to be whirled, readings may be taken where space is restricted, and chances of error which exist when a sling psychrometer is used by an unskilled operator are said to be largely removed through the use of the new instrument.

The hand aspirated instrument comprises a pair of thermometers in a 7½ by 1½ by ¾ in. case and a rubber bulb and reservoir with which a steady jet of air is induced by means of the venturi principle over the thermometer bulbs to give the true wet and dry bulb temperatures. Weight of the instrument is but 12 oz.

(b) The "windowstat" is a humidity sensitive instrument incorporating a multiple human hair element which is wired in series with the regular humidity control, the object being to cut off humidification when the relative humidity indoors approaches the point where condensation would occur on windows. The "windowstat" is mounted at the window which is the worst offender insofar as condensation is concerned.

(c) The electric recorders provide a means for the remote recording of relative humidity direct, as well as temperature. The relative humidity transmitter (in the duct, room, outdoors or wherever the humidity is to be measured) consists of a multiple human hair element, while the temperature transmitter is of bi-metal. The measurements are transmitted from the transmitter to the recorder (in the engineer's office, the building lobby, or wherever desired) by a pair of "Autosyn" synchronous positioning motors, one at each end of the low voltage electrical circuit. Distance between the transmitter element and the recorder may be several thousand feet; for short distance transmission (25 ft) of temperatures, instruments employing capillary tubes are available.—Julien P. Friez & Sons, Inc., 4 N. Central Ave., Baltimore, Md.

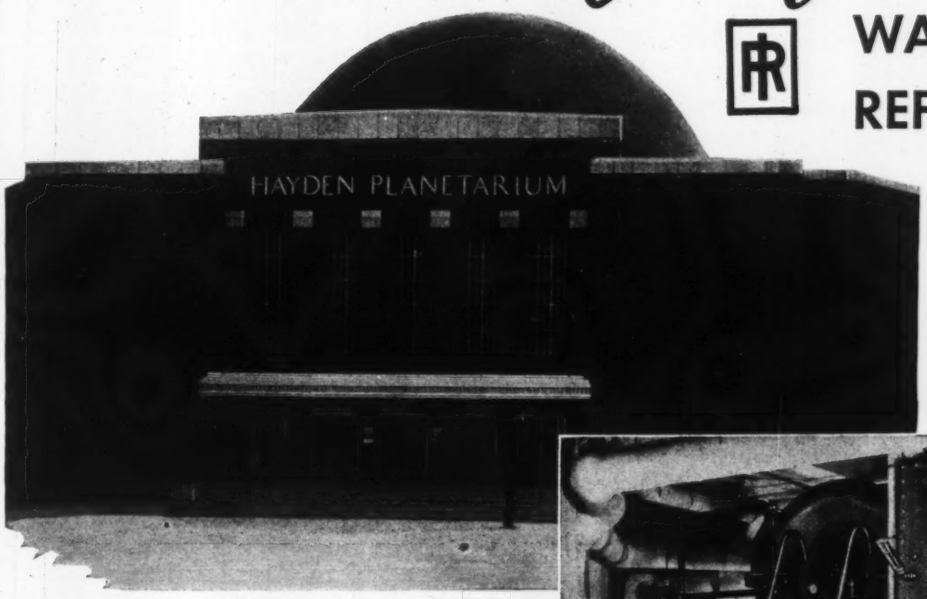
Air Eliminator for Steam Traps

No. 645—For removing entrained air from cold steam systems a new air eliminator has been developed for "Super Silvertop" inverted bucket steam traps. This device utilizes a "Spencer" thermostatic disc which takes the place of the usual thermal strip in blast traps. In the cold position, the disc curves out and away from three large auxiliary ports on the side of the inverted bucket. Air can then pass rapidly through the trap.

The eliminator remains wide open until the critical temperature (which accompanies live steam) is reached. It then snaps

The Touch of Refinement

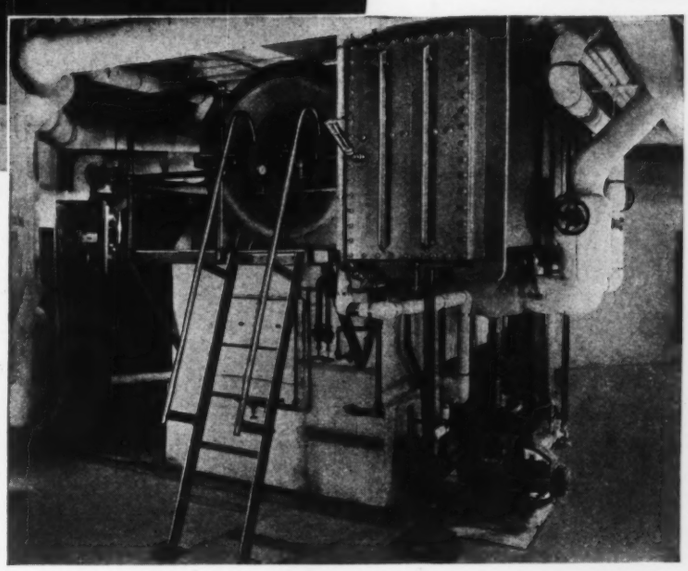
I-R WATER-VAPOR REFRIGERATION



TROWBRIDGE and LIVINGSTON
Architects

TENNEY and OHMES, Inc.
Consulting Engineers

WHITE CONSTRUCTION CO.
Builders



Comfort Cooling For Another Famous Building

IN the basement of the new Hayden Planetarium at the American Museum of Natural History in New York City is installed a simple and compact I-R Water-Vapor Centrifugal Refrigerating Unit which cools water for air conditioning the main auditoriums and halls.

It is driven by a direct-connected condensing turbine operated by exhaust steam from the electric light and power plant of the museum. Since this steam would normally be wasted during the warm weather months, the operating expense is practically nothing.

This is but one of the many successful I-R Water-Vapor Refrigeration installations now serving a wide variety of applications.

Water itself is the refrigerant. Cooling is accomplished by direct evaporation of a small quantity of water under a high vacuum, created by a centrifugal compressor. Water chilled by this evaporation is the cooling medium and is circulated directly to the air-cooling coils.

Advantages of I-R Water-Vapor Refrigerating Units

SIMPLICITY • SAFETY • SELF-REGULATION • FREEDOM FROM VIBRATION
SUSTAINED CAPACITY • OVERLOAD CAPACITY • NO REFRIGERANT LEAKAGE

Centrifugal units are available for either motor or turbine drive. Where steam and water costs permit, Steam-Jet Water-Vapor Refrigerating Units as built by Ingersoll-Rand have unique advantages.

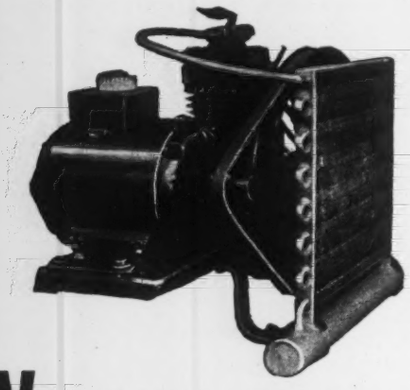
227-4

Birmingham, Boston, Buffalo, Butte, Chicago, Cleveland, Dallas, Denver, Detroit, Duluth, El Paso, Houston, Knoxville

Ingersoll-Rand

11 BROADWAY, NEW YORK CITY

Los Angeles, Newark, New York, Philadelphia, Picher, Pittsburgh, Salt Lake City, San Francisco, Scranton, Seattle, St. Louis, Tulsa, Washington



WAGNER MOTORS
are Well-Designed

Wagner motors conform to refrigerator and air-conditioner manufacturers' demands for auxiliary equipment that harmonize with the arrangement, utility, and construction of their equipment.

Every single item that has a definite bearing on the appearance of Wagner motors contributes to its mechanical efficiency. Drip-proof end-plates, for example (see Photo N445), protect the motor from falling dirt and liquids, and protect individuals from contact with moving parts. Ample ventilation is secured from openings located underneath the bearing housings.

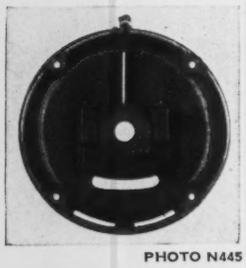


PHOTO N445

All parts and completed motors undergo careful and thoro tests according to all N. E. M. A. specifications,—your assurance of reliable, quiet, trouble-free, quality motors. Photo K1261 shows a view of one of the test boards with a motor undergoing tests.

PHOTO K1261

Wagner Bulletin 177, which completely describes the construction features of Wagner small motors, will be sent upon request.

S635-5B

Wagner Electric

MOTORS
TRANSFORMERS
FANS
BRAKES

6400 Plymouth Avenue St. Louis, U.S.A.

abruptly to the closed position, covering the ports. Trap then operates normally.

The eliminator is always either wide open for discharging air or tightly shut. Manufacturer states that this makes sure that there will be no delay in air elimination due to premature closing, and no steam loss due to slow closing.—V. D. Anderson Co., 1949 W. 96th St., Cleveland, O.

New Type of Insulated Ducts

No. 646**—New type of insulated duct construction comprises wire mesh of a special weave to which is applied "Zonolite" mineral insulation, a thermal and sound insulation. This application makes a solid covering and the insulation content gives it a low thermal conductivity; at the same time no sound absorbing liner is necessary as the "Zonolite" cover absorbs the noise through the mesh openings. The material is a micaceous, non-ferrous, granular substance impervious to fire, which, when expanded under high temperatures, takes on a leaf-like form and a bright golden color. Tests have shown its thermal conductivity to be 0.27, states the manufacturer, and resistance to flow of air only 5 per cent over an unlined sheet metal duct.—Zonolite Corp., Fisher Bldg., Detroit, Mich.

Low Pressure Freon and Methyl Units

No. 647—New line of condensing units comprises a full series of models designed for "Freon" and methyl chloride refrigerating systems, both commercial and air conditioning, including eighteen sizes ranging in capacities from ¼ to 25 hp.

Air-cooled models are equipped with shrouded condensers and are built in sizes from ¼ to 2 hp. They are especially suited for installations where an adequate or suitable water supply is not available, and where water costs are high. Water-cooled models are built in sizes from ½ to 25 hp. This style machine in the sizes from 3 to 25 hp have horizontal shell and tube condensers mounted on a heavy welded base, and are particularly well suited to air conditioning requirements. They have "V" type compressors of heavy duty pattern with discharge and suction valves built on the feather valve principle, all located in the heads to secure even temperatures.—Carbondale Machine Corp., Worthington Ave., Harrison, N. J.

Pipe Insulation for Cold Lines

No. 648—New type of pipe insulation for cold lines is known as rock cork pipe covering, and, like rock cork sheets, is made of specially water-proofed rock wool, thus being mineral in composition and inherently permanent in character. Most important feature of the material, according to the maker, is the factory applied waterproof jacket which provides, in addition to the moisture resistance of the material itself, a waterproof hermetic seal against infiltration of moisture laden air.

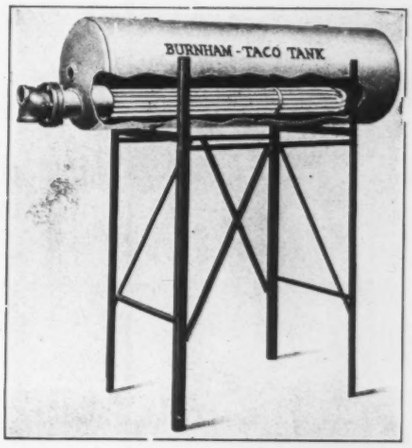
Fittings are insulated with multiple layers of "Zerotex," a waterproofed rock wool designed for the purpose, each layer of which is sealed with a double wrapping of waterproofed sealing tape; the insulation of the fitting is completed with a layer of an asphalt base plastic.—Johns-Manville Corp., 22 E. 40th St., New York, N. Y.

Steam Return System Reduces Fuel Costs

No. 649*—A new method of returning steam and condensate to the boiler at high temperatures is manufactured and sold by the American District Steam Co., North Tonawanda, N. Y., east of the Mississippi River and by the Becker Pump Co., Oakland, Calif., in the western territory. Installation of the "ADSCO-Becker" condensate and steam return system in industrial plants, canneries, dairies, laundries, paper mills and for other processes operating steam consuming drying, cooking and heating equipment has increased production from 15 to 40 per cent and effected fuel savings of from 15 to 25 per cent, according to the manufacturer.

The Burnham-Taco Tank

Has a Six Year Guarantee and Can Be Connected Below the Boiler Water Line



Note that the Taco coil goes practically full length of tank. The sturdy angle iron stand for the Taco-Tank is furnished separately—

You can connect the tank below boiler water line for all-year-round economical operation with oil, gas or stoker fed plants, and not in the least affect its efficiency.

Works on All Systems

Works equally well on steam, vapor or hot water systems.

Saves on Fuel

Take a look at that cut-away view of the tank above. Note that the copper coils go practically the full length of the tank. Approximately all of the water is in contact with the coil. It is plain to be seen it will give quick action and save fuel. The large heat transfer surface of the coil, coming in direct contact with such a volume of water in the tank itself, must cut down heat losses. It also materially reduces the operating time of the fuels burning.

Saves on Installation

You save on installation by using a Burnham-Taco Tank. You save on pipe, fittings and valves, as fewer are needed. Galvanized tanks are all built of copper bearing steel and tested to 300 lbs., which represents double extra heavy construction. Each tank carries a *six year guarantee*. Tanks can also be furnished in copper and Everdur.

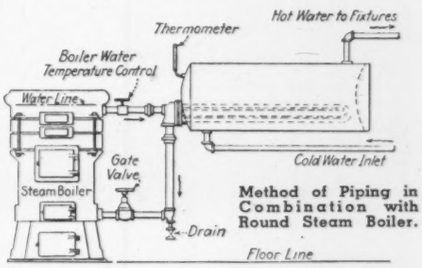
Profit

You always make as much profit, and nine-times-out-of-ten more, by using a Burnham-Taco Tank, than if you used the old style side-arm heaters.

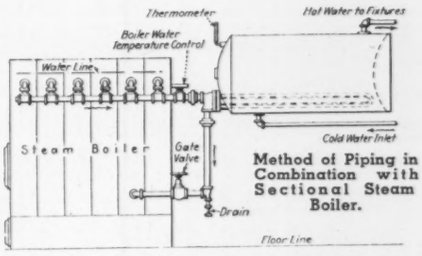
Furthermore

Furthermore, it's a Burnham product with Burnham's reputation and *unfailing guarantee* of satisfaction back of it.

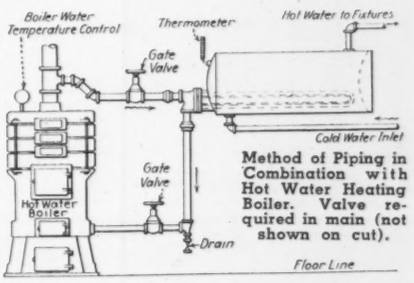
Send for printed matter. Get prices and the full facts. See for yourself.



Method of Piping in Combination with Round Steam Boiler.



Method of Piping in Combination with Sectional Steam Boiler.

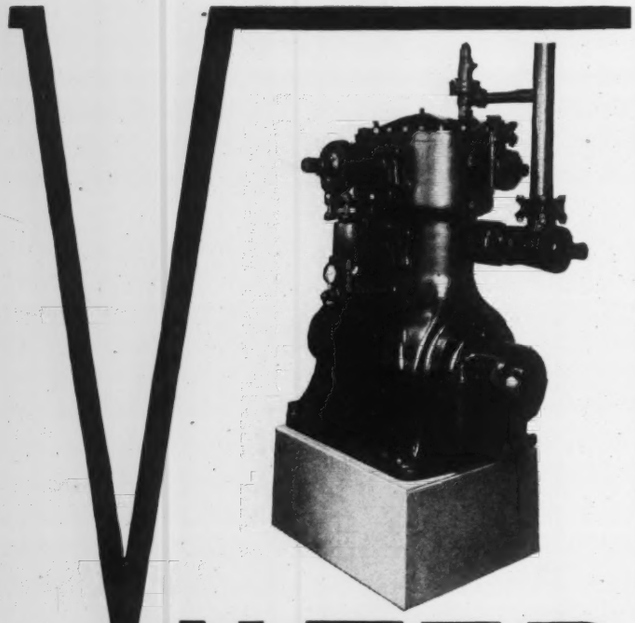


Method of Piping in Combination with Hot Water Heating Boiler. Valve required in main (not shown on cut).

Burnham Boiler Corporation

IRVINGTON, NEW YORK **ZANESVILLE, OHIO**

Representatives in all Principal Cities of the United States and Canada



VILTER

INTRODUCES A NEW COMPRESSOR DESIGNED FOR FREON

The modern trend toward air conditioning is a popular recognition of principles and practices that are old to Vilter.

Through nearly seventy years' service, Vilter has pioneered the development of equipment which has made air conditioning in its modern application basically possible.

Its latest achievement is the Vilter Freon Compressor, designed for applications where Freon is desired as a refrigerant. It assures long, dependable service with positive safety.

Commends itself especially for installations where human comfort or the preservation of perishables demand the utmost protection.

Whatever your requirements—human comfort or process air conditioning, whether large or small —you can look to Vilter with confidence.

FHA plans are available for any modernization program of air conditioning.

THE VILTER MANUFACTURING COMPANY "SINCE 1867"
2148 South First Street
MILWAUKEE, WISCONSIN
REPRESENTATIVES IN PRINCIPAL CITIES

The system is a compact piece of equipment which is motor driven, with one moving part. It is closed to the atmosphere from the boiler, through the steam using equipment and directly back to the boiler at any pressure and at temperatures ranging from 275 to 350 F, depending upon conditions. Advantages, says the maker, are heat loss is reduced to a minimum; less make-up water is required, boiler scale is reduced and boiler operation in general is improved. In some cases, present boiler pressures can be reduced by the system and a further saving made in fuel costs.—American District Steam Co., ADSCO-Becker Pump Div., North Tonawanda, N. Y.

Multiple Condensing Units for Air Conditioning

No. 650—For air conditioning installations requiring refrigeration capacity up to 100 or 200 tons using a common refrigerant system, a system utilizing standard condensing units operated in parallel has been developed. Special features consist largely of the method of equalizing the return of oil to the various machines operated in multiple, and the equalization of the oil level in the crank case of all machines without robbing oil from any machine during any part of the operating cycle. When machines are operating in parallel in this manner, a large common condenser is used for all machines, usually of shell and tube design. The control is arranged so that it is impossible for two of the motors to be started simultaneously.

The multiple type of installation has several advantages, it is stated. All machines in operation with this arrangement are worked at full load, providing maximum operating efficiency of the units at all times from light loads to full loads. The equipment can often be placed in a space which could not be utilized for a single large compressor. Special foundations are eliminated.

As an example of the application, eight condensing units operating in multiple produce approximately 160 tons of refrigeration for air conditioning the entire building occupied by Hale Brothers Department Store, Sacramento, Calif.—Westinghouse Electric & Mfg. Co., Mansfield, O.

Forged Steel Valves for High Temperature Service

No. 651—Improved forged steel globe valves just announced are made for pressure ratings up to 1500 lb and are specially designed with a tongue-and-groove bolted bonnet for high temperature service. They are made in either cone or plug type and the valve seat ring and disc are of heat treated stainless steel. The makers claim that this trim material is exceptionally hard, and therefore resists wire drawing, indenting, and galling and reduces repairs.

Features include all parts made of steel for safety against fire hazards; long condensation chamber to protect and increase life of packing; all wearing parts renewable; seat ring easily removed with a standard hex wrench. The makers state that these valves are easy to repack in service because of a special stainless steel back seat; and because the gland bolts come completely out allowing ample finger room and because of a relief plug for bleeding condensation chamber while repacking.—Consolidated Ashcroft Hancock Co., Inc., Hancock Valve Div., 11 Elias St., Bridgeport, Conn.

Seamless Alloy Tubes and Pipe

No. 652—Commercial production of seamless tubes and pipe of a highly alloyed steel containing 25 per cent chromium and 20 per cent nickel has been announced. These products are available hot finished in sizes up to 6 in. outside diameter and cold drawn in smaller sizes.

This alloy has a high degree of oxidation resistance and is suitable for continuous operation at temperatures up to approximately 2100 F, says the manufacturer. It is a ductile material possessing greater creep strength and resistance to oxidation at high temperatures. Its properties are such that it will undoubtedly find a field of usefulness in high temperature cracking, polymerization and other refinery operations, as well as for

U. S. Pat. 2,023,749

SURFACE

Cataloged on a Package Basis

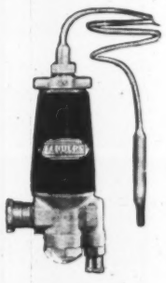
Men who design, sell, install and operate air conditioning systems are simplifying their work with Fedders Air Conditioning Surface. Cataloged on a Package Basis, it saves hours of time in laying out and estimating.

Fedders Surface gives you high prime surface, completely manifolded. With Fedders Model 33-HC High Capacity Thermostatic Expansion Valves, it makes a complete Low Side.

Write for Bulletin 91-A.

Check These Fedders Features

1. ALL COPPER and brass construction.
2. Factory engineered manifolding assures proper distribution of refrigerant to all rows and eliminates hazards of field assembly.
3. All joints welded with Phos-Copper welding alloy.
4. Tested with 300 lbs. pressure and approved by Underwriters' Laboratories.
5. Thoroughly cleaned and dehydrated.



FEDDERS *High Capacity* THERMOSTATIC VALVE

Easy, sensitive adjustment helps get greatest effectiveness out of each section of coil. U. S. Pats. 1,974,631; 1,987,948.

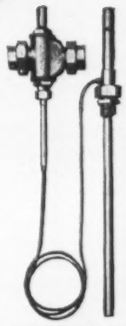
FEDDERS MFG. CO.

57 Tonawanda St. Buffalo, N. Y.

New York • Chicago • Cincinnati • Dallas
Los Angeles • Atlanta

ARE YOU GETTING YOUR COPY OF THE FEDDERS NEWS?

Windowless Department Store Installs SARCO Heating System and Temperature Regulators

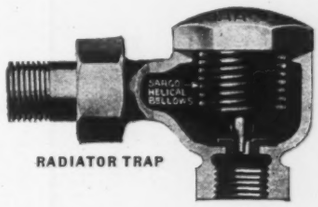


TEMPERATURE REGULATOR

Entirely without windows, except for four slim spires of glass above each entrance, this new department store of Sears, Roebuck & Co., Chicago, demonstrates a new idea in architecture.

This novel structure is equipped throughout with Sarco Radiator Traps and brine Temperature Regulators.

Sarco products were chosen for this building because it has been proven beyond question of doubt that they give dependable service over a longer period of years.



RADIATOR TRAP

Without obligation, we will gladly help work out your heating and temperature regulating problems.

Write for catalog O-45.

SARCO CO., INC.

183 Madison Ave. New York, N. Y.

Branches in Principal Cities

SARCO CANADA LIMITED
Federal Building, Toronto, Ontario, Canada

Underground Steam Piping with Conduit and Insulation COMPLETE Ready to Install!

(Right) Part of 95 Units as delivered and ready for installation. Note that RicwiL Unit Steam Main has plenty of supporting strength for use under railroads.

(Left) 3 Units welded together above ground, ready for backfill, showing RicwiL pre-fabricated Unit Manhole, with self-contained expansion device.

(Right) Close-up view, unretouched, of conduit in trench with asphalt coating applied, and connector liner raised to show Dry-paC insulation — ready for final installation of conduit Connector band.

THESE pictures show a recent installation of RicwiL Unit Steam Main for an industrial concern. A durable, compact, light-weight System designed for economy and speed. Completely assembled at factory, including pipe and supports, insulation, liner, and Armco Iron conduit, ready to install, with welder and common labor. Shipped in units 13½ feet long. Famous genuine Dry-paC Waterproof Asbestos insulation. Trenching reduced to an absolute minimum. Reclamation value practically 100%—can be moved and installed elsewhere. Total installed cost is the lowest for any satisfactory job. Utility test reports and complete details on request.

The Ric-wiL Co., Union Trust Bldg., Cleveland, Ohio
New York ● San Francisco ● Chicago
Agents in principal cities

REGISTERED IN U. S. PATENT OFFICE
RICWIL
CONDUIT SYSTEMS FOR UNDERGROUND STEAM PIPES

high temperature equipment such as recuperators, thermocouple protection tubes, valves, and heat resistant tubular members.—The Babcock & Wilcox Co., 85 Liberty St., New York, N. Y.

New Fin Type Electric Heating Unit

No. 653—New fin type "Calrod" heating unit has been developed, principally for air heating, where the air is forced over the heating units, and for such applications as the heating of air conditioned railway cars on electrified lines, building heating, and various types of unit heaters.

The unit consists of a steel sheath heating element with steel fins copper brazed to the steel sheath. The copper brazing process provides excellent thermal contact between the fins and the unit sheath and delivers an increased amount of heat in a given space for a given rating.—General Electric Co., 1 River Rd., Schenectady, N. Y.

New Industrial Air Conditioning Units

No. 654—New line of industrial air conditioner units, designed to meet a wide range of industrial air cooling requirements with a maximum cooling effect and low operating costs, incorporates improved features of design and construction, developed as the result of an exhaustive study of industrial applications of refrigeration. The units, designated as "FB-500," "FB-800," "FB-1400" and "FB-2000," can be installed in any industrial plant, with or without distributing ducts.

Furnished in either the high or low pressure type, the automatic float control permits accurate and automatic control of the refrigerant, whether ammonia, circulating brine or cold water is used, says the manufacturer. Where circulating brine or cold water is used as a refrigerant, special coils and headers are furnished, to insure minimum power requirements for pumping.

The entire unit is enclosed in heavy, braced steel casing. Fans are of the quiet operating multiblade, double inlet type, providing low outlet velocities, with V-belt drive to insure flexibility of speeds, and allowing for the ready adjustment of air volume to meet specific requirements.

Cooling and dehumidifying surfaces have been given special attention. Coils are of ¾ in. full weight pipe, bent from single lengths, and fabricated into all-welded units, which are equipped with stands to give them stability. After bending the coils are annealed to eliminate all internal strain. They are tested under water, both before and after galvanizing, to insure gas tight construction.—York Ice Machinery Corp., Roosevelt Ave., York, Pa.

New Motor for Air Compressors, Pumps

No. 655—To meet demand for a single phase motor with a smooth torque-speed curve, efficient starting features of the repulsion motor, and the approximately constant speed load operation of the induction motor, the "SR" single phase motor has been developed. At the present time, 1725 rpm motors have been developed in 1, 1½, 2, and 3 hp ratings.

The "SR" motor has an armature with both a squirrel cage winding and a repulsion or commuted winding. Both windings operate as such at all times; the commutator of the repulsion winding is not short circuited as the motor attains speed and the squirrel cage is not opened at slow or starting speeds. The starting action is smooth and steady and the starting commutation is excellent, according to the maker. There is no heavy sparking with resultant pitting of the commutator.

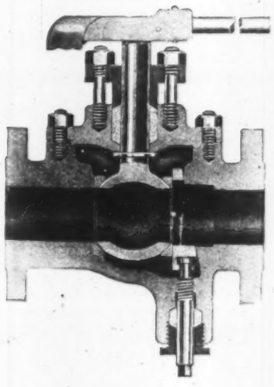
As a result of these characteristics the motor is suited to starting and bringing to speed sustained heavy starting loads, such as an air compressor at very low temperatures which congeal the oil. Commercial refrigerators, pumps, grinders, choppers, mixers and other devices which may offer a heavy starting load or in which starting is greatly prolonged because of excessive friction are also applications.—The Emerson Electric Mfg. Co., 502 N. First Ave., St. Louis, Mo.

Fairbanks Sphero Ball Valves give a FULL ROUND OPENING the same as the nominal size opening of the pipe line, eliminating frictional resistance to stream flow.

They shear right through gritty or scaling fluids as well as thick viscous materials. Because of the perfect seating of the ball to the seat rings an absolutely tight, leakproof seal is assured with

Fairbanks Sphero Valves

A simple outside adjustment takes up wear on seat rings and ball plug. Should they eventually require renewal, that can be accomplished in less than a half hour without removing valve from the line or disturbing pipe covering. One man, instead of two, can easily do the job.



Fairbanks Sphero Valves will be especially appreciated when used for blow-off purposes.

Write for our new catalog No. 21, illustrating and describing more than 140 different types of valves.

THE FAIRBANKS COMPANY

Manufacturers of Valves, Hand Trucks and Wheelbarrows

396 Lafayette St., New York, N. Y.

Boston, Pittsburgh—Distributors in Principal Cities

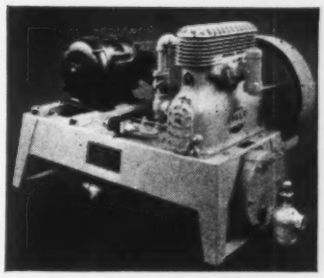
Factories: Binghamton, N. Y., and Rome, Ga.

"WORKING FOR THE COUNTY"

● Jury decisions in this fine new Jefferson County Courthouse at Beaumont, Texas, are really the result of deliberation. Heat and humidity never become factors in forcing a compromise—Baker Air Conditioning keeps air in the jury room cool, clear of smoke, properly dehumidified and in positive, gentle motion. Baker Units will be found "working for the county" in all parts of America—courthouses, state and governmental institutions are quite familiar with Baker dependability and low cost of operation.

Jefferson County Courthouse, Beaumont, Texas, with Baker Comfort Cooled Jury Room

● Write for our new folder describing the entire Baker line of "Freon" and methyl-chloride automatic units. Four cylinder type shown at right is one of more than 60 models in capacities from ¼ h. p. to 30 h. p.



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Centrifugally Cast Threaded Cast Iron Pipe

No. 656—"Super-deLavaud" cast iron pipe is now being manufactured in "steel pipe sizes" with threaded joints. There are two distinct types of service for which this pipe may be used, pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra strong and double extra strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Tentative Federal Specifications TS-206S, Type A.

Every piece of this cast iron pipe is subjected to a hydrostatic pressure test of 1000 lb per sq in. to assure a pipe free from defects and of sufficient strength to withstand stresses from chain or Stillson wrenches employed in assembling the joint.

The fact that "Super-deLavaud" pipe is now supplied in "steel pipe sizes" enables it to be used in conjunction with standard screw joint fittings of any make without the need of an adapter. It is readily machinable and may be drilled, tapped, cut and threaded with the tools in the average steamfitter's kit.—United States Pipe and Foundry Co., Burlington, N. J.

New Dust Collector Announced

No. 657—Heart of the "American Dustube" dust collector is a long tube made of a specially woven fabric which can be changed to meet the specific installation. The tubes are hung from racks in the ceiling, and self acting dust seals hold the tubes to the bottom without clamps or bands. Seal is positive in operation, states the maker, and spring suspension of the tubes maintains proper tension on the cloth making it easy to insert or take out dust tubes when desired.

Each tube works independently and if damaged can be unhooked, rolled up, and placed in the inlet seal at the bottom, sealing off the opening temporarily and not interfering with operation of the other tubes.—The American Foundry Equipment Co., 555 Byrkit St., Mishawaka, Ind.

New Units for Air Conditioning

No. 658—New air conditioning units recently announced have furniture steel cabinets finished to simulate walnut, circulating water coils of cadmium plated copper, aluminum castings, and all steel parts are cadmium plated. Size is 36 in. high, 22 in. maximum width, and 12 in. deep. Weight is 165 lb.

Air is drawn through outside duct connection by three speed fan operating at 1250, 900, or 450 rpm to deliver 300, 200, or 100 cfm. For winter operation, air passes over 12 in. by 18 in. finned copper radiator and then through humidifying spray, then through solid wool filter. Storage chamber provides for "medicating" the air if desired.

Unit may be supplied with chilled water for cooling and dehumidification. Motor is a-c induction type, 1/20 hp, 110 volt. Quantity of water used is 16 gph states the maker.—Miller Conditionair Co., 1138 S. Broadway, Los Angeles, Calif.

Universal Socket Dial Thermometers

No. 659.—New Universal socket dial thermometer is manufactured in both self contained and distant reading types. The "Type 61" self contained instrument fitted with the universal socket permits the use of the one instrument as a vertical connection thermometer, a 90 deg back angle thermometer, a front angle thermometer or any intermediate angle, eliminates the requirement of specifying a specific type of stem for each particular application.

The "Type 62" distant reading thermometer is standard with

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BULLETIN 351

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6 ft. of connecting tubing and a union bulb or, in the case of high temperature thermometers, either a union bulb or a flexible plain bulb. The thermometer has a mounting flange together with the universal socket which permits the installation of the instrument proper at any convenient point on top or in front of the apparatus or on a wall or pillar and then to install the bulb right at the point of temperature.

A complete assortment of Fahrenheit scale ranges for all requirements from 20 below zero up to 800 F above (or corresponding Centigrade scales) is available.—Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Ill.

Scraper Cleans Pipe Line Strainer in Service

No. 660—A modification of the well known type of circular screen pipe line strainer is fitted with either a plunger or rotary scraper within the screen to enable the screen to be cleaned without removing it. Thus, the device is particularly suited for use on oil lines and other services where the flow is continuous, and may take the place of more expensive duplex strainers.—Sarco Co., Inc., 183 Madison Ave., New York, N. Y.

Automatic Motor Base

No. 661—Following development of the motion control variable pitch "Texrope" sheave for V belt drives, a "Straitline" automatic ball bearing motor base has been announced; the base provides a convenient place from which to operate the variable pitch sheave and maintains a uniform belt tension throughout the speed range adjustment. A dial indicator shows the tension on the V belts, eliminates guess-work.

According to the maker, this base "places the motor on wheels"; four ball bearings, totally enclosed and lubricated for the life of the unit, support the motor and the upper half of the base to assure ease of operation with minimum sliding friction. Travel of the base is in a straight line and base is always securely anchored to its foundation.

The dial indicator enables maintenance of proper belt tension to prolong belt life. The hand wheel on the base controls the speed of the variable pitch sheave and simultaneously moves the motor a sufficient distance to compensate for the change in centers between shafts resulting from the change in diameter of the sheave.—Allis-Chalmers Mfg. Co., Milwaukee, Wis.

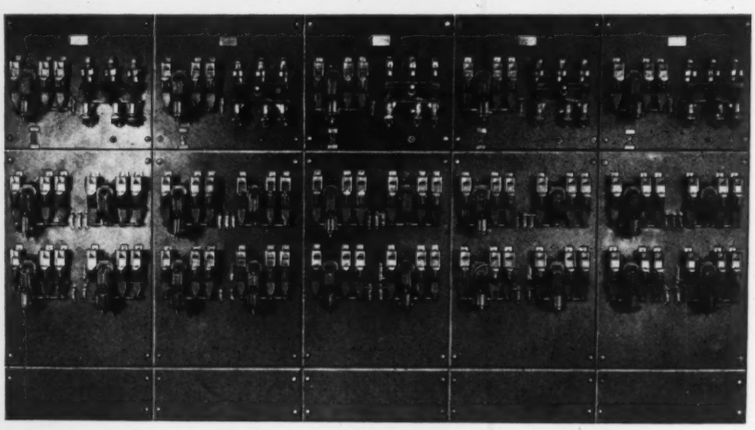
New Unit Air Conditioners

No. 662—New "U.A.C." unit air conditioners for apartments, hospitals, stores, and other buildings, on display for the first time at the Fourth International Heating and Ventilating Exposition last month, may be used to replace existing radiators for year-around air conditioning. Heating capacity with a copper heating coil and cast brass headers is the equivalent of 80 sq ft of direct steam radiation, and with cast iron coil, 63 sq ft. Cooling capacity is 1 ton with copper coil; chilled water at 40 F will develop ¾ ton, states the maker. Air delivery is 150 to 400 cfm as desired.

Motor is 60 cycle, 1/100 hp, shaded pole, a-c, heavy duty, 900 rpm, 110 volt. D-c motor available at slight additional cost. Filter is 1 in. removable steel wool interchangeable type, and an evaporating type constant level humidifier with automatic feed is used. Construction is of gray cast iron.

Cabinet is 23 in. high, 30 in. long, and 12 in. deep and has a photographic baked enamel finish.—Burnham Boiler Corp., Main St., Irvington, N. Y.

Clark-Sundh



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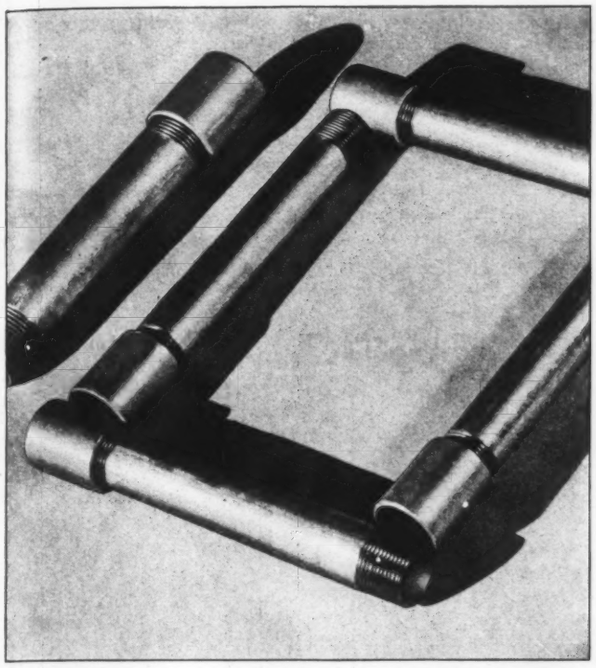

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Because it is (1) made of highest quality materials; (2) absolutely uniform; (3) tightly welded; (4) perfectly round and true to size; (5) straight; (6) accurately threaded; (7) clean inside and outside; (8) easy to bend, cut and thread and free from hard or burnt spots in the metal; (9) easy to install and less expensive to use; (10) and in the case of galvanized finish, protected against rust by a non-scaling zinc alloy surface.

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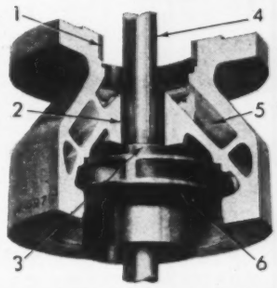

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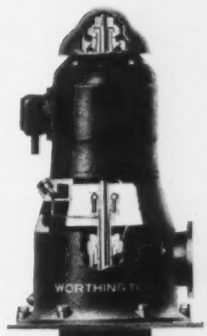

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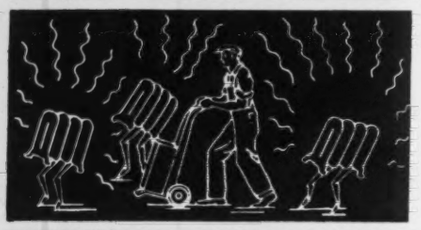

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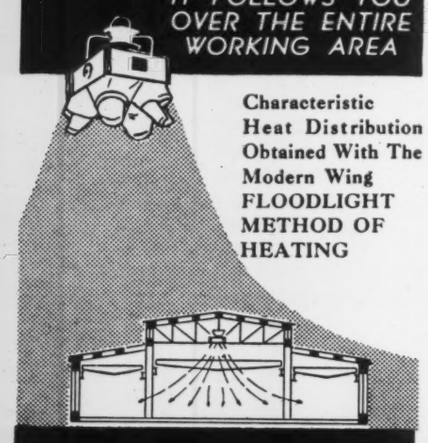

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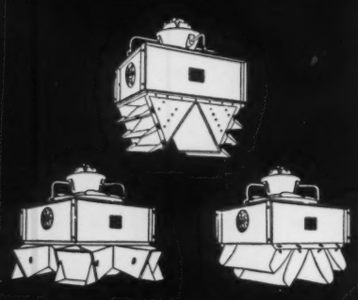

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Booklets, Reports and Papers

Psychrometric Charts in Pad Form

The Trane Co., La Crosse, Wis., is offering a pad of psychrometric charts, helpful in figuring air conditioning problems. Issued in this form, the charts may be marked on in working out a problem and the sheets filed with the other calculations if desired. Brief instructions accompany each pad, which are available for 35c.

Air Conditioning as a Career

The Institute for Research, 537 S. Dearborn St., Chicago, Ill., has recently issued a 16 page survey of air conditioning as a career. Following a brief analysis of the development of air conditioning and air conditioning equipment (in which it is pointed out that air conditioning really supplements the two fifty year old fields of ventilation and heating), the fields of air conditioning and types of installations are discussed. Under the heading "Training and Opportunities," opportunities in air conditioning are divided into designing, manufacturing, and selling, each of which "offers almost infinitely expanding opportunity," according to the report. The air conditioning engineer, the air conditioning mechanic, the air conditioning sub-contractor, and the air conditioning dealer are considered at some length, and personal qualifications and obstacles are given attention.

Copies may be had for $1.00.

Boiler Water Troubles and Treatments

The Engineering Experiment Station, Oregon State Agricultural College, Corvallis, Ore., has published a 52 page bulletin entitled "Boiler Water Troubles and Treatments with Special Reference to Problems in Western Oregon," by R. E. Summers, Assistant Professor of Mechanical Engineering. A review of what is now established in boiler water chemistry is presented to set up briefly in convenient form a practical background for boiler operators. Following this, problems encountered in western Oregon are outlined, which include "some of the most usual and yet some of the most unusual."

Sections into which the report is divided comprise the introduction, importance of the problem, peculiar and unusual water conditions in western Oregon, boiler ills and their causes, water treatments and their advantages and limitations, and possibilities of rational boiler water treatment in western Oregon. Numerous tables and curves, and a bibliography of 78 references, are included. The price is 25c.

Directory of Thermal Research

The 1936 directory for the correlation of thermal research issued by the Research Laboratory of the *American Society of Heating and Ventilating Engineers,* 4800 Forbes St., Pittsburgh, Pa., is a 29 page listing of universities, government bureaus, technical societies and associations, trade associations, and private laboratories engaged in and supporting research, codification, standardization or improvement in practice in thermal engineering, with special reference to heating, ventilation and air conditioning. A cross-index by subjects under investigation is included.

Small Commercial Refrigeration Plants

In "Elements of Refrigeration for Small Commercial Plants"—recently published by the Engineering Experiment Station, Oregon State Agricultural College, Corvallis, Ore.—Wallace H. Martin, Professor of Heat Engineering, presents information on the fundamentals of mechanical refrigeration to meet the need for knowledge on the part of owners and operators of small plants and to assist in economical operation. Principal attention is

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The COMFORTROL
Maintaining true Effective Temperature, even with simple heating or cooling equipment. How soon will it obsolete the house Thermostat?

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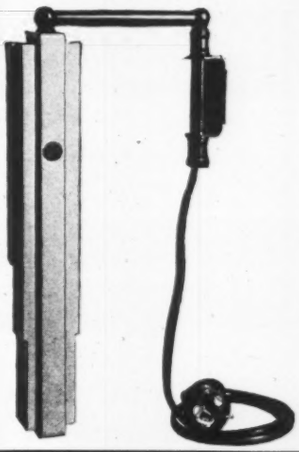
It stops winter condensation on windows before condensation starts.



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"Three problems that have stumped air conditioning engineers and blocked the progress of the industry have been solved by your firm in the simplest and most original way."

The three problems in reference:

1. How to provide Effective Temperature automatically --we give you the Friez Comfortrol.
2. How to prevent automatically winter condensation on windows--for that . . . the Windowstat.
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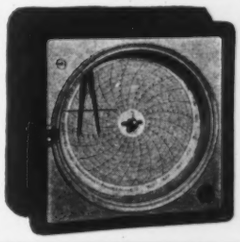

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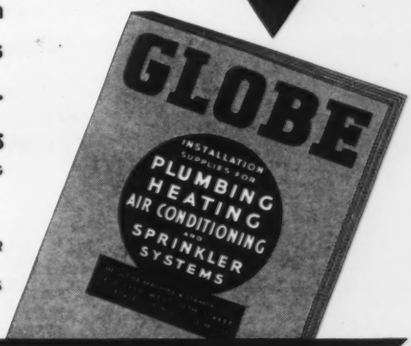

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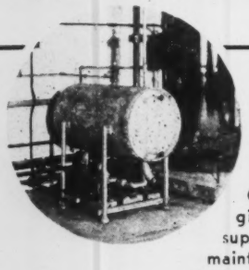

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Operated electrically, this unit gives economical control of water supply . . . AUTOMATICALLY maintains a constant water level . . . pumps feed water against high boiler pressure . . . returns condensate to boiler . . . supplies make-up water as needed.

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given to refrigeration for dairies, ice cream, and ice manufacture, although much of the material is of course of value in connection with other applications.

The refrigeration cycle is described in some detail, illustrative calculations are given, heat transfer is discussed, and general information on check valves, corrosion, charging and flooded operation presented. The appendix comprises a saturated ammonia-temperature table, charts of volumetric efficiency and theoretical performance, and a table of heat transfer coefficients. Price of the circular is 25c.

Municipal Housing

The National Public Housing Conference, 112 E. 19th St., New York, N. Y., has just published a 36 page pamphlet by Helen Alfred, its secretary and director, in which the municipal housing problem is outlined and discussed. The five chapters are entitled The Urban Housing Problem, Housing Problem Essentially Economic, Municipal Housing Progress, Federal Emergency Program, and An Established Housing Service.

Book Reviews

Graphical Solutions

"Graphical Solutions," by Charles O. Mackey, Assistant Professor of Heat Power Engineering, Cornell University. Published by John Wiley & Sons, Inc., New York. 130 *pp.*, 6x9 *in., clothbound, with loose chart. Price,* $2.50.

Outgrowth of a course offered for many years to mechanical engineering students at Cornell, this book is not a treatise on graphical computations but a most practical text and reference for engineers and students. Most of the examples can be handled with a working knowledge of logarithms, algebra, and a few principles of plane geometry.

A graphical or mechanical representation of an equation which must be solved many times may be justified through minimizing error and by contributing to ease of solution. The first four chapters are concerned with stationary adjacent scales, sliding scales, network or intersection charts, alignment charts and combinations of them. As the fitting of equations to experimental data is a task that frequently confronts the engineer, the fifth and last chapter discusses methods of determining the values of the constants in non-periodic equations.

The examples presented throughout the text involve problems familiar to heating, piping, and air conditioning engineers. A chart of logarithmic scales is furnished with the book.

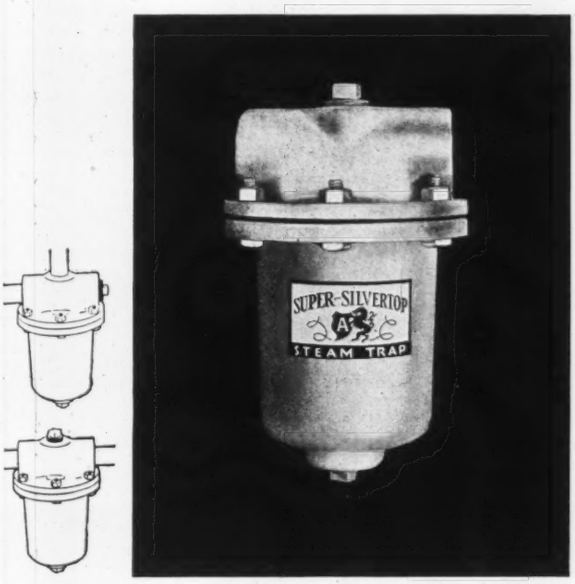
Boiler Reference Book

"The Pape-Swift Boiler Reference Book, 1936," published by John S. Swift Co., Inc., St. Louis, Mo. Planographed, 321 *pp.;* 5¼x8¼ *in., paper-bound. Price,* $1.00 *plus* 10c *postage. Available from Keeney Publishing Co.,* 6 *N. Michigan Ave., Chicago, Ill.*

This third edition of the Pape-Swift boiler reference book does not duplicate the 1934 or 1935 editions, but supplements them with data on boilers not previously included. Some 42 manufacturers are represented in the 1936 volume, and the three books now list the boilers of 76 manufacturers and cover the specifications of over 900 models.

Prime purpose of these references is to make information on boiler numbers, grate area, heating surface, and manufacturers ratings easily and conveniently available to engineers, architects, contractors, and the heating trade. The tables are reproduced directly by the planograph process from the individual manufacturers publications.

A master index for the 1934, 1935 and 1936 editions is now available from the publisher and is furnished free with each order; additional copies may be had for 15c.



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The Anderson Super-Silvertop is the only complete trap, ready for installation between steam unit and return line.

NO STRAINER IS NECESSARY

Super-Silvertops take care of dirt and scale, since there are no delicate parts to become injured nor small passages to become clogged. You don't pay extra for a strainer.

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Elbow facilities are cast in the head of the Super-Silvertop steam trap, permitting an elbow connection in either direction. You don't pay extra for elbows.

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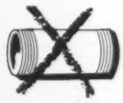

since no elbows are needed. You don't pay extra for nipples.

• In comparing costs of steam traps remember that the price of ordinary traps does not include the fittings and strainers needed. For an honest price comparison, the additional cost of these necessary parts should be added to the cost of ordinary traps. Super-Silvertop is a complete trap—no other fittings are needed.

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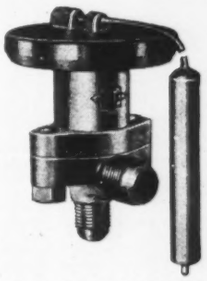
The New ALCO THERMO VALVES *are Small in Size and Light in Weight*

SMALL IN SIZE

The new Thermo Valves are the type of valves that you knew would some day be made. Here are valves that will operate perfectly either inside or outside the cold area, at any angle with either side up.

They are SMALL IN SIZE, compact in design and sturdy in construction. Their size provides ease of handling under all conditions and permits easy installation in close quarters.



SIZES

From 2⅝" x 3 11/16" to 3" x 4¾" Overall dimensions.

SERIES T VALVES

Series T Valves are furnished with internal or external superheat adjustments.

WEIGHTS

From 1¾ pounds to 3 pounds.

LIGHT IN WEIGHT

Light weight is an important factor in installation and handling. These midget valves prevent sagging of lines and eliminate the necessity for valve supports. They are easily and quickly installed with a minimum of effort.

Look to Alco for the latest development in accurate refrigeration controls.

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• For complete descriptions of Series T Thermo Valves, ask for Bulletin 144-C.

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PIPE AND FITTINGS

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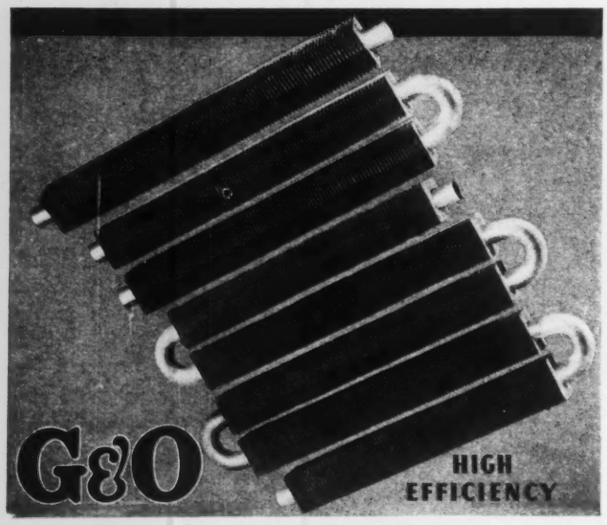

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WE are splendidly equipped to supply high efficiency Finned Tubing and Complete Coils for all heat transfer purposes.

Special Shapes, Bends and Continuous Coils

Correspondence invited.

The G&O Manufacturing Co., New Haven, Conn.

Pioneer Manufacturers of Individual Square Fin Tubing in the United States

The Editor's Correspondence

To Modernize with New Central Heating Plant

THE EDITOR—We are planning the installation of a small central heating plant to heat three buildings on a campus separated from our main campus. The radiation will approximate 4000 to 6000 sq ft in each building. The relative locations of the buildings and the mains are shown on the enclosed sketch.

The science building now has a one pipe steam heating system with a cast iron sectional boiler in the building. Another building has a two pipe gravity system with a down draft boiler in the building. The library has individual room gas heaters.

Our plan is to construct a boiler house and coal pocket on the west side of the science building. As I have not yet obtained the services of a heating engineer I shall greatly appreciate it if you can give me a general opinion regarding the type of system to install. What pressure would you suggest?

In this section we can obtain help for firing low pressure equipment at a considerably less cost than the higher class help which would be required for higher pressure equipment.—L. O. A., Director, Buildings and Grounds.

REPLY—The most remote building is about 370 ft from the proposed boiler house. The sketch accompanying the inquiry showed the plan-relation of the buildings, but gave no information concerning the relative elevations of the buildings.

They are all old structures, each requiring about 60 boiler horsepower. One building has individual room located gas burning heaters, and therefore must have a complete new heating system if it is to be served from a central plant. One building has a two pipe gravity steam system and one has a single pipe gravity steam system.

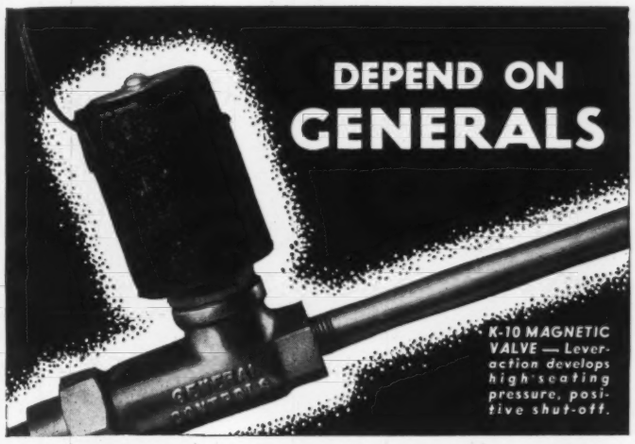
The proposed layout of mains indicates an intention to run around right angles, though a considerable cost in investment and heat loss could be saved by a diagonal crow flight sort of layout utilizing the basements of the buildings. There may be good reasons, such as trees, right-of-way, allowance for other future buildings, etc., back of the rectangular proposal.

One cannot tell whether or not the boiler house may be placed sufficiently underground to permit gravity steam circulation, but this seems rather doubtful, the probability being that the supply main must leave the boiler room at a level below that of the boiler water line.

It is not wise to make a recommendation as to the kind of plant without more information, but the tendency based on the scanty premises is toward two low pressure steel boilers, preferably with electric automatic stokers, and with capacity such that either boiler can carry the present load. This would make some allowance for future additions and would provide a reserve unit against any need for repairs. The boilers would operate at up to about 15 lb pressure in the mains with a pressure reducing valve in each building so that the pressure there may be regulated to suit the requirements of each heating system. Thus the old single pipe or air vent system will require 2 or 3 lb pressure to "clear its throat" of air, while a more modern plant with vacuum traps would be excessively hot with 1 lb pressure. The old single pipe system would have a new float trap on its return connection to the underground vacuum suction line.

The new heating plant for the old gas heated building would be a modern two pipe vacuum system, with a measure of temperature control due to pressure variation. It would be wise to install a master thermostat in each building, preferably against an outside wall, controlling the steam supply to the building.

The old two pipe heating system easily could be converted to two pipe vacuum by installing thermostatic traps at all return connections. An electric vacuum pump would be placed in the boiler room and would keep the underground mains drained even though they might be lower than the boiler water line.



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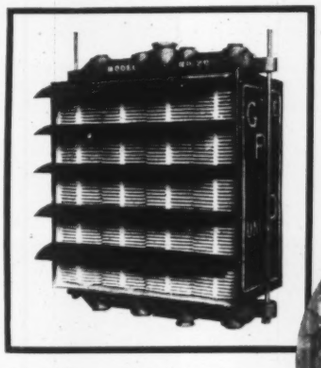
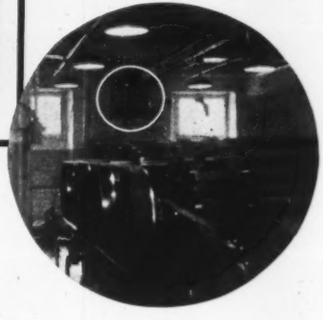


GRID UNIT HEATER



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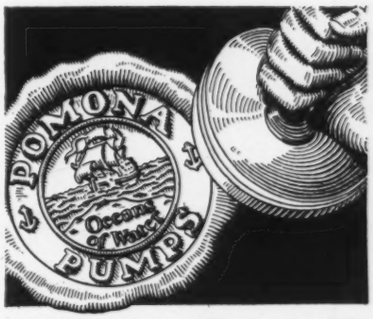

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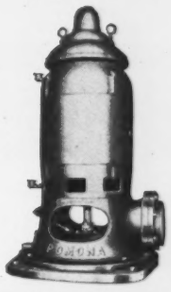

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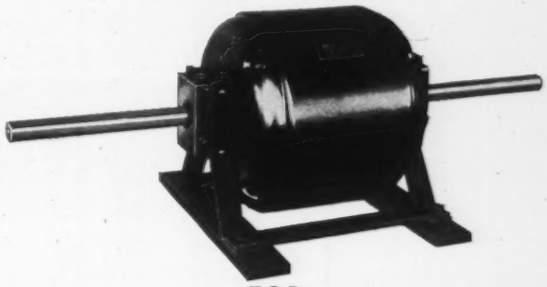

FOR
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WRITE FOR BULLETIN No. 20

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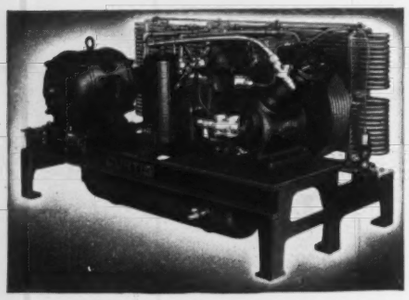

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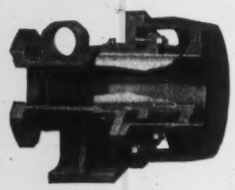

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The underground mains should be most carefully graded so as to drain, and should be insulated with non-organic and waterproof material, with a rock filter and a drain tile under every inch of it, connected to a sewer or its equivalent. Expansion and anchorage of this underground service should have attention.

Substantial savings in the investment cost of underground piping, insulation, and manholes and underground heat loss are possible by running the lines directly to the buildings and through the basements. Of course it may be undesirable to disfigure the basements with the piping. On the other hand these old basements may not be in use for any other purpose.

Many institutions have installed central heating systems upon incompetent designs and have regretted the move because of wasted fuel and heavy reconstruction costs.

In the case of this institution the designs for the complete equipment could be made by a competent engineer at a cost which would be merely a reasonable insurance premium against future trouble.—Samuel R. Lewis.*

*Consulting Engineer, Chicago, Ill. Member of Board of Consulting and Contributing Editors.

Conventions and Expositions

Welding Conference: February 13-14. Texas Technological College, Lubbock, Tex.

Southern Industrial Show: April 6-11, Textile Hall, Greenville, S. C. Wm. G. Sirrine, President.

National Oil Burner Show: April 14-18, Convention Hall, Detroit, Mich. Managing Director, G. Harvey Porter, Oil-Burner Institute, Inc., 30 Rockefeller Plaza, New York, N. Y.

Great Lakes Exposition: July-September, Exposition Hall, Cleveland, Ohio. General Chairman, Dudley S. Blossom, Terminal Tower, Cleveland, Ohio.

Heating, Piping and Air Conditioning Contractors National Association: Annual convention, May 25-27, The Bellevue-Stratford, Philadelphia, Pa. Educational Director, S. Lewis Land, 1250 Sixth Ave., New York, N. Y.

National District Heating Association: Convention and exhibit, June 16-19, Pantlind Hotel, Grand Rapids, Mich. Acting Secretary, Miss M. C. Stocker, 124 W. Fourth St., Greenville, Ohio.

American Society of Heating and Ventilating Engineers: Joint semi-annual meeting with *American Society of Refrigerating Engineers*, June 22-24, Buck Hill Falls, Pa. Secretary, A. V. Hutchinson, 51 Madison Ave., New York, N. Y.

International Refrigeration Congress: June 16-27, The Hague and Amsterdam.

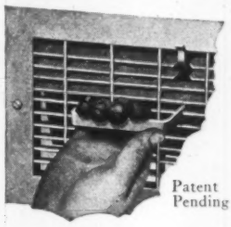
Short Course in Coal Utilization: June 9-11, University of Illinois, Urbana, Ill. A. C. Callen, Head of the Department of Mining and Metallurgical Engineering, 209 Transportation Bldg., Urbana, Ill.

American Society for Testing Materials: Annual meeting, June 29-July 3, Chalfonte-Haddon Hall, Atlantic City, N. J. Assistant Secretary, R. E. Hess, 260 S. Broad St., Philadelphia, Pa.

Recent Trade Literature

For your convenience in obtaining copies of bulletins, see coupon on page 103.

No. 788. AIR CONDITIONING: Ilg Electric Ventilating Co., 2850 N. Crawford Ave., Chicago, Ill. 14 p. booklet "Sensible Ventilation—A Phase of Air Conditioning," reprint of a talk by P. D. Briggs before the Boston Air Conditioning Bureau, stressing ventilation as a step toward air conditioning, citing tests of effectiveness, and discussing attic cooling of apartments and other applications.



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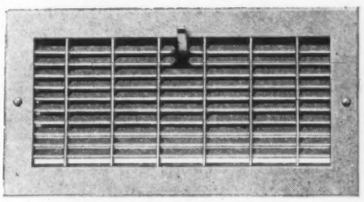

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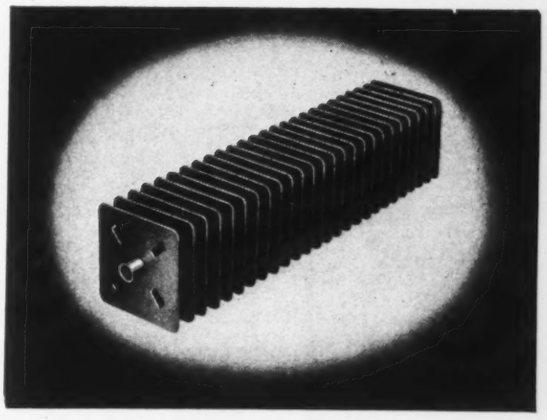

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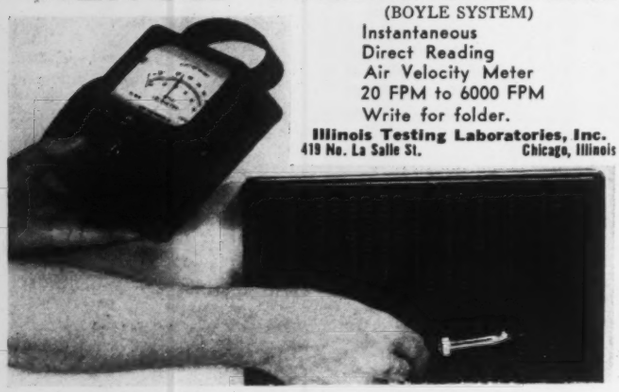
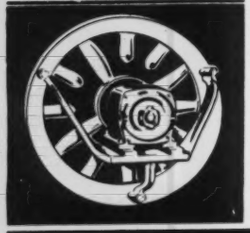


Fans



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No. 789. AIR DIFFUSERS: Knowles Mushroom Ventilator Co., 41 N. Moore St., New York, N. Y. 8 p. catalog of air diffusers of various types giving descriptions and engineering information with specifications for installing, as well as list prices.

No. 790. ALLOYS: The International Nickel Co., Inc., 67 Wall St., New York, N. Y. 8 p. booklet listing exhibits at the Cleveland Machine Tool Show, in which nickel alloy steels and cast irons were employed.

No. 791. COMPRESSOR LUBRICATION: The R. & H. Chemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. 6 p. issue of "Artic Service News" featuring article by E. W. McGovern on the lubrication of methyl chloride compressors, with data on solubility, dilution, viscosity, foaming, return of oil from high side, dry expansion and flooded evaporators, and desirable characteristics of oils.

No. 792. COILS: Frick Co., Waynesboro, Pa. 4 p. bulletin describing refrigeration coils and giving complete information on features and applications.

No. 793. CONTROL: Julien P. Friez & Sons, Inc., 4 N. Central Ave., Baltimore, Md. 2 p. "educational sheet" on the importance of effective temperature in air conditioning.

No. 794. CONTROL VALVES: Frick Co., Waynesboro, Pa. 12 p. bulletin on electric control valves for refrigerating plants, giving complete information, dimensions, applications and descriptions of features; several diagrams show applications.

No. 795. ELECTRICAL CONTROLS: Monitor Controller Co., Baltimore, Md. New bulletins and list prices for direct current and alternating current controls, including starters, magnetic controls, push button stations, float and limit switches, pressure and vacuum regulators, etc., giving descriptions of features and details.

No. 796. FANS: Emerson Electric Mfg. Co., 502 N. 1st St., St. Louis, Mo. 28 p. catalog of fans, including ceiling fans and exhaust fans.

No. 797. FANS: Torrington Mfg. Co., 70 Franklin St., Torrington, Conn. 4 p. bulletin giving performance tables and dimensions for small diameter propeller fans.

No. 798. FANS: Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo. 16 p. bulletin on fans, including propeller ventilating fans, air circulators, ceiling and exhaust fans.

No. 799. INSTALLATION SUPPLIES: Globe Machine & Stamping Co., 1220 W. 76th St., Cleveland, O. 20 p. catalog of installation supplies for heating, air conditioning and sprinkler systems, including pipe hangers, clips, clamps, floor and ceiling plates, etc., giving complete information, drawings and dimensions.

No. 800. HEAT EXCHANGE EQUIPMENT: Struthers-Wells Co., Warren, Pa. 16 p. bulletin describing line of heat exchange equipment.

No. 801. HEATING SURFACE: J. J. Nesbitt, Inc., Holmesburg, Philadelphia, Pa. 4 p. bulletin describing features of heating surface with steam distributing tubes, showing cut-away view and three diagrams showing this surface applied to central station air conditioning systems to give continuous steam valve control.

No. 802. INSULATION: The Ruberoid Co., 500 Fifth Ave., New York, N. Y. 36 p. catalog giving data and tables on "Ruberoid-Watson" heat and cold insulating products, including asbestos pipe coverings, 85 per cent magnesia, mineral wool, insulating paper and board, and asbestos cements. An appendix includes fundamental data, insulating material specifications for heating and ventilating systems, list prices, weights, heat loss tables, etc.

No. 803. IRON AND STEEL: The American Rolling Mill Co., 703 Curtis St., Middletown, O. 16 p. booklet telling the story of how "Armco" iron has been brought to the public attention.

No. 804. MACHINES: Niagara Machine & Tool Wks., 637 Northland Ave., Buffalo, N. Y. 18 p. bulletin covering complete line of machines for cutting circles and rings and for slitting and flanging for use in the sheet metal industry.

No. 805. PIPE AND SHEETS: Republic Steel Corp., Central Alloy District, Massillon, O. Folder stressing the advantages of corrosion resisting "Toncan" iron pipe and sheets for air conditioning, picturing typical installations.

No. 806. PUMPS: Worthington Pump & Machinery Corp., Harrison, N. J. 8 p. folder on deep well turbine pumps, including a large size cross-section view showing details of pump, the passage of the water from the suction opening to the discharge, and illustrating bearing and lubrication details. Features are described and typical applications illustrated.

No. 807. REFRIGERATING UNITS: Frick Co., Waynesboro, Pa. 4 p. bulletin describing and giving data on two new low pressure refrigerating units with overhead drive.

No. 808. REGULATORS: Powers Regulator Co., 2720 Greenview Ave., Chicago, Ill. 4 p. bulletin on hot water tank regulators, picturing various applications and featuring installation in Union Trust building, Pittsburgh. Also, 4 p. bulletin showing schools, colleges and universities using this company's automatic temperature control.

No. 809. STEAM TRAPS: Armstrong Machine Wks., 874 Maple St., Three Rivers, Mich. 12 p. bulletin "What Every Greenhouse Man Should Know About Steam Traps," including information on fuel saving; operation of traps; sizes and list prices; selection, installation and maintenance; and condensate drainage systems.

No. 810. UNIT COOLERS: Fedders Mfg. Co., 57 Tonawanda St., Buffalo, N. Y. Issue of "Fedders News" (Vol. 2, No. 12), featuring article by L. J. Freitas on the application of unit coolers in a hospital nursery and operating rooms at Baylor University Hospital, Dallas, Tex.

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651	652	653	654	655	656	657	658	659
660	661	662						
788	789	790	791	792	793	794	795	796
797	798	799	800	801	802	803	804	805
806	807	808	809	810	811	812	813	

Name..... Title.....

Company .....

Address .....

No. 811. UNIT HEATERS: Surface Combustion Corp., 2375 Dorr St., Toledo, O. Issue of "Janitrol Journal" (Vol. 2, No. 1), featuring article by A. H. Koch describing use of gas fired unit heaters in the shipping of fruit, showing the application of equipment to fruit house.

No. 812. VALVES: Haynes Stellite Co., Kokomo, Ind. 8 p. bulletin on "Haynes Stellited" valves for high temperature, high pressure steam service, with information on freedom from wire-drawing, galling or seizing, and corrosion by hard facing steam valves with this cobalt-chromium-tungsten alloy.

No. 813. WATER VAPOR REFRIGERATION: Ingersoll-Rand, 11 Broadway, New York, N. Y. 4 p. folder on cold water for air conditioning and industrial use, briefly describing steam jet and centrifugal type water vapor refrigeration units and "Cameron" pumps for water circulation. Also, 4 p. folder on water vapor refrigeration for cooling gas to remove objectionable constituents, in order to save on pumping out pipe lines and on repairs and service cost from trouble caused by condensibles in meters, valves, pilots, etc.

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